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QUALITY OF APPLES FOR HOUSEHOLD USE

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histological, chemical, and palatability studies

AGRICULTURAL RESEARCH SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

QUALITY OF APPLES FOR HOUSEHOLD USE

histological, chemical, and palatability studies

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Agricultural Research Service

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HOME ECONOMICS RESEARCH REPORT No. 8

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One of the authors, Andrea O. Mackey, has transferred to the Home Economics Department, Oregon State College, Corvallis.

QUALITY OF APPLES FOR HOUSEHOLD USE

histological, chemical, and palatability studies

SUMMARY AND CONCLUSIONS

Histological structure, chemical composition, palatability, and cooking quality of six varieties of apples before and after storage were evaluated in this study. The quality of Delicious, Golden Delicious, Jonathan, Rome Beauty, Stayman, and Winesap apples was evaluated in raw apples, in applesauce, and after baking.

The microscopic structure of the apple skin was related to the quality of the apples used in this study. Good storage quality was indicated by a smooth and homogeneous cuticle showing few interruptions, deep staining capacity, and low incidence of birefringent bodies in hypodermal cell walls, and intense overall staining capacity and low incidence of rupture and birefringent bodies in cortex cell walls.

Values for the several chemical constituents studied showed distinct variations among the six varieties. Total acidity of apples showed highly significant correlations with tartness of raw apples, applesauce, and baked apples. Natural flavor was more closely related to total acidity in sauces than in raw and baked apples. When raw, apples high in acidity usually had a crisp flesh texture, but when baked showed a tendency to lose their shape. Scores for sweetness, natural flavor, and tartness were likewise highly correlated with reducing-sugar content.

Flavor characteristics—natural flavor, absence of off-flavor, sweetness, and tartness—in raw apples, applesauce, and baked apples influenced general acceptability more than other palatability factors. Sauces receiving high scores for color likewise received high scores for general acceptability. A positive relationship between it and texture in sauces indicates that the more smooth, less granular sauces were considered most acceptable. Correlations between scores for consistency and scores for general acceptability indicate that the judges considered the thinner sauces most acceptable. The baked apples most acceptable to the judges had some cracking of skin and some softness but not mushiness of flesh texture, as shown by a positive coefficient of correlation between scores for flesh texture and scores for general acceptability and a negative correlation between scores for wholeness and scores for general acceptability.

Consideration of flavor and texture characteristics of the apples used in this study indicated that high harvest quality and proper storage conditions were essential in maintaining high eating quality during storage. The most noticeable changes in palatability of raw apples during storage were a decrease in natural flavor and an increase in mealiness of flesh texture. Most sauces and baked apples likewise showed decreases in natural flavor and were less translucent after storage of the apples; also, sauces were thinner and baked apples were softer.

It is known that consumer preferences exist for varying degrees of sweetness or tartness, firmness or softness of apples for eating raw. Nevertheless, from judges' ratings all apples in this study that were of good harvest quality were acceptable for eating raw before storage and after storage for as long as 5 months at 40° F. and for 6 months or more at 32°. In general, the same was true for apples used in making applesauce and baking. Delicious apples, though not commonly considered a cooking apple, made acceptable sauce from apples freshly harvested or stored no more than 3 months. Jonathan and Stayman apples of higher acid content made smoother, thinner sauces than the other varieties. Jonathan and Rome Beauty made better baked apples. When of good harvest quality, Golden Delicious made acceptable baked apples. Delicious and Winesap baked apples had tough skins and hard flesh texture; hence, were less acceptable, as were Stayman baked apples because of soft and mushy texture.

PURPOSE OF THE STUDY

In volume produced and in economic value apples are the most important of the deciduous fruits. They hold this position partly because of the wide distribution of important growing areas and partly because of the seasons through which apples are available as fresh fruit for consumer use. In recent years apple production in the United States was highest in 1949, when a total crop of 134 million bushels was reported (*48*).[1] In 1958 a commercial production of over 124 million bushels of apples was reported (*47*).

A few varieties account for the bulk of the apple production; the most important ones in 1948–49 were Delicious, Winesap, McIntosh, Jonathan, Rome Beauty, and Stayman. In the New England States trends in new plantings are in favor of Cortland and McIntosh. Plantings of Delicious and Golden Delicious are increasing in all other areas. In addition, Rome Beauty and Stayman are becoming more plentiful in the North Atlantic States; Jonathan and Rome Beauty are on the increase in the North Central States; in the South, plantings of Jonathan and Stayman are increasing; and in the Northwest, Winesap also is gaining in favor.

About one-third of the commercial apple crop is marketed and consumed in the fall. The larger part of the remainder is usually held in the producing area under cold storage until marketed during the winter and spring months (*28*). Apples produced by the small grower for his own use, and those purchased in quantity for family consumption are likewise stored under household conditions and drawn upon as a fresh fruit supply from fall until the following spring.

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[1] Numbers in parentheses refer to Literature Cited, p. 76.

Deterioration of apples in storage may be in the form of rot, scald, softening, shriveling, or other types of physical breakdown. Varieties show these changes in different degrees. When present, such defects cause lowered consumer acceptance, resulting in total rejection or markdowns and thus greater economic loss than actual percentage deterioration would indicate.

Changes in consumer quality of apples resulting from household storage are important because of the variation in harvest quality of apples obtained from home or local farm orchards and the length of time most apples are held. Information as to eating and cooking qualities of mature and immature apples of each of the major varieties related to the storage properties, should be helpful to consumers in their selection of apples for specific uses.

This study was planned to determine the cooking and eating qualities of several apple varieties important in the total supply and to determine the relation of these properties to selected physical, histological, and chemical characteristics.

Such information may serve as a guide in predicting eating and cooking qualities and may be used as a basis for recommended practices in procurement, use, or method of preparation for each variety. Knowledge of histological structure and chemical composition as related to palatability may serve as a guide to the plant breeder in his propagation of desirable characteristics in apples.

REVIEW OF LITERATURE

The recommended storage condition for most apple varieties is a temperature of 30° to 32° F. with a relative humidity of 85 to 90 percent. At this low temperature, ripening of the fruit is delayed and chemical changes proceed at a slower rate (*13, 53*). The conditions of low temperature and high humidity recommended for apple storage can be provided commercially. In contrast to this, apples stored at home seldom are kept under ideal conditions. Temperatures around 40° with no humidity control may more closely approximate household storage conditions.

The wilting and softening of different varieties of apples during storage has been studied in relation to the extent of cutinization and skin thickness, as well as the average size of cortex cells. Less wilting during storage was observed by Magness and Burroughs (*24*) for the thickskinned Delicious, Rome Beauty, and Winesap varieties compared with thinner skinned varieties. Cummings and Lombard (*10*) observed that apples having small cells together with thicker skins were better keepers. On the other hand, Smith (*40*), after a study of two English varieties, stated that apples with thinner cuticle and larger cells kept better. Perry and Martin (*32*) reported a direct relation between thickness of the cuticle and records of keeping quality of different varieties of apples. Clements (*9*) showed that exchange of gases and transpiration of water occurred chiefly through the cuticle rather than through the lenticels. Pieniazek (*34*) believed that thickness of the cuticle alone was not a factor, but that the amount of wax on the cuticle regulated the rate of gas and moisture exchange to a large extent. The rate was greater in apples with large areas of russet.

In addition to the development of visible defects, apples undergo internal chemical and physical changes during storage. These changes

affect both flavor and texture; hence are of significance through their influence on consumer reaction.

The chemical components of apples are known to be important in determining their keeping qualities (*42*). Some, as the nitrogenous compounds affect the rate of respiration; and others, namely acids and sugars and possibly pectins and hemicelluloses, furnish reserve respirable material.

There appear to be few studies relating the structure to the composition of cooked apples. Milam and Gardner (*31*) published drawings of a few cortex cells from cooked apples of three varieties; Whittenberger (*51*) made pressure tests of six varieties after cooking. Saburov, Dudkina, and Kaperina (*37*) made chemical analyses of the pectins, hemicelluloses, and other substances before and after cooking.

It has been generally assumed that softening of apple parenchyma during senescence (*8, 16*) and cooking (*51*) is due to cell separation, resulting from a change or decrease in pectic substances and failure of the middle lamellae to hold the cells together. However, evidence obtained from histochemical studies of uncooked apples (*12, 52*) and comparable tissues in cooked carrots, parsnips, and potatoes (*50*) indicate that other changes may be involved, at least in cooking. Softening during cooking may be related to acid hydrolysis of hemicelluloses (*37*).

Stokdyk (*43*) in California reported that consumers gave highest preference to good flavor or taste in apples to be eaten raw. When used for cooking, pleasing texture as well as good flavor and acidity are desired qualities (*33*).

French's [2] survey of consumer demand for apples in New York City and Liston's (*20*) in Vermont showed preference among some consumers for green apples for cooking. The purchase of green apples is due to selection of specific green varieties, preference for immature apples for special cooking purposes, or absence of mature apples from the market. Approximately 36 percent of the New York families interviewed preferred green apples for cooking.[2] In California about 40 percent of the consumers interviewed (*43*) purchased early, immature apples—more than half of them for cooking. The acidity of immature apples or a price differential may govern choice, since it is generally agreed that full flavor and sweetness are not found in immature apples.

The cooking quality of 71 varieties of mature Oregon apples was studied by Milam and Gardner (*31*), who reported a relation between the microscopic structure of different varieties and the characteristics of sauce. Varieties having a low proportion of pith and vascular tissue and those having large cells with low cohesion yielded the best quality of sauce. Apples good for eating raw were not necessarily good for sauce, pies, dumplings, jelly, and marmalade.

Pfund (*33*), using from 13 to 15 varieties of New York apples, studied the influence of certain characteristics on appearance, texture, and flavor of baked apples and sauce. Personal opinion ratings of "good" for flavor of cooked apples were associated with relatively high acidity and short storage periods. Flavor ratings of "good" in cooked apples were also associated with firmness of the raw fruit and natural, aromatic, and spicy flavor qualities. Texture ratings were influenced by tenderness of raw fruit, juiciness, firmness, and meltiness.

[2] FRENCH, E. R. CONSUMER DEMAND FOR APPLES IN NEW YORK CITY. U.S. Bur. Agr. Econ. [Unpublished.] July 1927.

Ratings for appearance of sauce were most influenced by color and by consistency. Average scores for acidity of cooked apples were closely related to the pH values of the raw juice.

EXPERIMENTAL PROCEDURES

Selection and sampling of apples

Varieties of apples used for this study were Delicious, Golden Delicious, Jonathan, Rome Beauty, Stayman, and Winesap. Delicious and Rome Beauty varieties were obtained in 1948 from orchards of the Crops Research Division at Beltsville, Md. These apples were picked when they had crisp flesh and were considered suitably mature for storage. The four remaining varieties were obtained from a local commercial orchard. The Golden Delicious and Stayman varieties were crisp and firm; cracks through the skin were prevalent in the Stayman. All apples of the Jonathan variety were bruised and some showed cuts and wormholes. Winesap apples were received late in the season; some were bruised and they appeared to be fully ripe.

Two pickings each of Golden Delicious and Stayman, immature and mature, and one picking of mature Jonathan apples were obtained from a local commercial orchard in 1949. Delicious and Rome Beauty varieties were again obtained from the orchards of the Crops Research Division. They were picked when most of the apples were at the hard-ripe stage. The under-ripe apples, as judged by color, were separated from those more fully red and mature. These selected under-ripe apples were classed as immature, together with those of other varieties that had been picked at an immature stage.

All apples were sorted and stored in bushel baskets or wooden boxes as soon as possible after they were received. Controlled storage at 32° F. with 85 to 90 percent relative humidity was furnished by the Marketing Research Division; 40° storage (uncontrolled humidity) was available in the Human Nutrition Research Division. Dates of picking and dates when apples were put into storage are given below:

Variety and maturity of apples	*Date picked*	*Date stored*
Delicious:		
Mature, 1948	Sept. 24	Sept. 24
Mature, 1949	Sept. 28	Sept. 28
Immature, 1949	Sept. 28	Sept. 28
Golden Delicious:		
Mature, 1948	Sept. 21	Sept. 28
Mature, 1949	Oct. 7 [1]	Oct. 12
Immature, 1949	Sept. 16 [1]	Sept. 22
Jonathan:		
Mature, 1948	(2)	Oct. 19
Mature, 1949	Sept. 26 [1]	Sept. 29
Rome Beauty:		
Mature, 1948	Oct. 14	Oct. 14
Mature, 1949	Oct. 17	Oct. 18
Immature, 1949	Oct. 17	Oct. 20
Stayman:		
Mature, 1948	Oct. 1 [1]	Oct. 6
Mature, 1949	Oct. 4 [1]	Oct. 7
Immature, 1949	Sept. 27 [1]	Sept. 30
Winesap:		
Mature, 1948	(2)	Nov. 30

[1] Approximate. [2] Unknown.

Apples of each variety and stage of maturity were divided into seven lots of about 1 bushel each. One lot was analyzed within a few days after harvest, and the remaining lots were analyzed after storage of 3, 5, and 7 months at 32° F. with 85 to 90 percent relative humidity (representative of commercial storage) or at 40° with no humidity control (representative of household storage). Winesap apples were studied only in 1948, since those available in 1949 were of poor quality

when harvested and were not considered representative of the variety. These lots furnished samples for overall estimates of deterioration, histological study, chemical analysis, and palatability testing.

For histological study, sections were prepared from raw and steamed unstored and stored samples from the second year's crop. Microscopic sections and photomicrographs were made to provide material for histological study. Chemical analyses on raw samples were made during both years to determine pectic substances, total sugars, reducing sugars, pH, total acidity, and moisture. Palatability of the apples was determined both years on three replications each for unstored and stored samples when raw, baked, and made into sauce.

Measurement of deterioration of apples in storage

Upon removal from refrigerated storage, each lot of apples to be used for testing was checked and counts were made to ascertain the amount of rot, softening, and shriveling that had taken place during storage. During the first year any deterioration of the apples was noted and recorded as an estimated fraction of the whole. Throughout the second year, apples showing each type of deterioration were counted and percentages of loss were calculated on that basis. After rotted apples were discarded, representative samples were selected for use in palatability judging, for histological study, and for chemical analysis.

During the second year weight loss was determined on special lots consisting of 28 apples representative of each variety, each stage of maturity, and each storage temperature. Individual apples were numbered, permanently marked, weighed when first received, and weighed again at each storage interval. Weights for apples that developed rot during storage were deducted. Weight loss was computed for the remainder on the basis of percentage loss at each period compared with that of the unstored sample.

Histological techniques

For the histological phases of this study, maturity, storage tem perature, and storage period of each variety of the second crop was represented. Every sample was studied in both raw and steamed condition, and after being stained by two procedures. Information was desired on the histology and histochemistry of apples as a group, on varietal differences among apples, and on the effects of storage and cooking on their microscopic appearance.

Apples for microscopic study were washed, dried, cored, and cut crosswise. One slice about one-fourth of an inch thick was cut from each cored apple. Two segments of skin, one from the stem end and one from the blossom end, were taken from the same apple. Skin segments were treated with 0.75 percent hydrochloric acid (*26*) and preserved in 70 percent ethyl alcohol. Later they were stained with Sudan IV, peeled or scraped, preserved in 50 percent glycerin, and examined for russet.

The peripheral 5 mm. portion of the slice was cut into cubes of appropriate size for fixing. Some cubes from each apple were immersed immediately in a solution containing 50 ml. of formalin, 50 ml. of glacial acetic acid, and 900 ml. of 70 percent ethyl alcohol. This solution will be referred to hereafter as FAA. Other cubes,

which were to be steamed, were placed in perforated crucibles on a rack in a covered kettle. Part of these specimens were steamed for 15 minutes, and others for 45 minutes. They were then immersed in FAA. All specimens were fixed in FAA for 24 hours or longer, raw-fixed specimens being kept in a low-pressure chamber during the first half hour and steamed-fixed specimens for a full 24 hours, in order to remove all possible intercellular air or gas from the tissues.

Dehydration and paraffin infiltration were accomplished by the tertiary butyl alcohol method (*17*). Sections 10 microns thick were cut from paraffin-embedded cubes. The stains found most helpful for distinguishing cellular structures were ruthenium red and diphenylene diamine acetate. These stains, heretofore recommended for use as microchemical reagents in temporary mounts (*14*, *17*), were adapted for use in permanent slides (*21*).

Microchemical tests for pectic or related substances and for pentosans were carried out on paraffin sections. The tests for cellulose were the iodine and zinc chloride test of Artschwager (*1*) and the sulfuric acid and iodine test described by Barrows (*4*). Cellulose was extracted from a few slides with cuprammonium hydroxide made as directed by Shetlar (*38*). Some of the sections were extracted by methods of Mehta (*29*) adapted to slides and tests applied for pectins or cellulose.

Both brightfield and polarized illumination were used in examining the slides. Measurements were made with an ocular micrometer and 16 mm., 4 mm., and 1.8 mm. objectives as needed. Photomicrographs were made with Kohler brightfield illumination, and with polarized illumination using a carbon arc as the light source.

Chemical analysis

Apples were analyzed chemically for certain constituents in order to determine the relation between the chemical composition and the palatability of the raw and cooked apples at each storage period of the apples. Moisture, total or reducing sugars or both, total or titratable acidity, and pH of the juice were determined by official methods of analysis (*2*). Total pectin and pectic acid were determined by precipitation as calcium pectate (*7*).

In each test, 20 apples were taken as the sample for analysis, scrubbed with a brush in running tap water, rinsed in distilled water, and dried with cheesecloth. The apples were cored, cut in half at right angles to the core, and quartered by cutting again from stem to blossom end. Diametrically opposite quarters were taken from each apple.

Quarters from 8 apples were grated and blended in an electric blender for approximately 3 minutes. Duplicate weighed portions taken for moisture determinations were dried in a vacuum oven for 24 hours to near constant weight. Separation of the juice from the pulp was achieved by draining through prepared cheesecloth. The juice was used for the determination of pH with calomel-glass electrodes and an electronic pH meter. Titratable acidity was determined on 2 aliquot portions, using N/10 sodium hydroxide and the indicator phenolphthalein.

Quarters from the remaining 12 apples were used for determining sugars and pectins. In order to facilitate handling, 6 quarters from 3 apples were taken at one time. A weighed portion of 110 grams was

obtained by radially trimming the 6 quarters. This portion was quickly and thinly sliced into hot 95 percent ethyl alcohol and boiled for 10 minutes. From 12 apples a combined total of 440 grams was prepared in 1600 ml. of alcohol. The material was then stored in glass-stoppered bottles until used for analysis of pectin, pectic acid, and total solids.

Determination of total solids was made on the alcohol mixture in order to calculate sugars and pectins in terms of dry weight of the apple sample. For analysis, 100-gram portions were weighed from the thoroughly mixed apple-alcohol suspension. These were filtered and the filtrate and washings reserved for determination of total sugars and reducing sugars. The residue was refluxed with 100 ml. of N/30 hydrochloric acid for 30 minutes, then neutralized with N/10 sodium hydroxide, and after the addition of 15 ml. of 10 percent ammonium citrate was refluxed again for 30 minutes. The hot mixture was filtered, the residue washed with distilled water, and the filtrate and washings made up to a volume of 250 ml. Duplicate 50 ml. portions of this filtrate were used for pectic acid and total pectin determinations. Pectins were hydrolyzed with sodium hydroxide to pectic acid, which was precipitated along with naturally occurring pectic acid as calcium pectate. Differences between the weights of the calcium salts of pectic acid and total pectic acid were calculated as pectin with reference to the dry weight of the apple sample.

Methods of preparation and cooking

Standardized methods for laboratory preparation of the apples were established and used consistently throughout the study.

Preparatory to judging raw apples for eating quality, representative samples of 3 or 4 apples each were removed from storage 7 hours before time for judging, to allow them to warm to room temperature. Just before being judged, they were washed, wiped dry, cored, cut into twelfths, and enough prepared segments mixed together to make 1 pound (454 grams). Five segments from the mixed lot were randomly selected for each judging sample.

Apples for sauce were pared, cored, and cut into uniform segments. One hundred fifty-eight ml. of water was added to 454 grams of the prepared apple, which was then cooked in a covered saucepan by gas heat. A thermometer was inserted through a hole in the saucepan cover and held in place by a cork. After the temperature reached 100° C. (212° F.) cooking was continued for designated lengths of time. During the first year's study, cooking periods of 10, 15, and 20 minutes were used to determine whether cooking time should be modified according to variety or for stored apples. On the basis of results obtained the first year, the 15-minute period was used exclusively throughout the second year's study. After cooking, observations were recorded as to retention of shape of the apple segments. The cooked apples were then sieved in a household food mill using 75 turns. Sugar in a ratio of 1 part to 5 parts by weight of sieved sauce was stirred in using 75 strokes. All sauces were cooled to room temperature before they were sampled for palatability judging.

Apples for baking were selected for uniformity of size. They were washed, wiped dry, and cored except for removal of the blossom end. The baking sample consisted of 4 or 5 apples weighing within 10 grams of each other, totaling 680 grams. Thirty-four grams of sugar was

added. Apples were baked at 400° F. in covered dishes without added water (*33*). Internal temperatures of one apple in each dish and oven temperatures were taken by means of iron-constantan thermocouples attached to an automatic recording potentiometer. Baking procedures differed slightly in the 2 years. The first year, after an internal temperature of 212° F. (100° C.) was reached, apples were removed from the oven and allowed to remain covered while cooling. The second year, after the same internal temperature was reached, baking was continued for 5 minutes to compensate for rapid heat loss due to cooling uncovered.

Palatability evaluation

The palatability of apples, raw, baked, and made into sauce, was evaluated by a panel composed of five persons experienced in judging apple quality. In three replications of the experiment the panel rated the following characteristics for raw apples, sauce, and baked apples: Natural flavor, absence of off-flavor, sweetness, tartness, texture of flesh, and general acceptability. In addition, scores were obtained for the following: Color of skin, color of flesh, and texture of skin of raw apples; wholeness, translucency of flesh, and texture of skin of baked apples; color, translucency, and consistency of applesauce. The judging records used by the panel are shown on pages 10, 11, and 12.

Most of the quality factors under consideration were rated on a numerical scale of 1 to 5, in which 5 represented the highest score. For the characteristics of sweetness, tartness, texture of flesh, and for applesauce consistency, a scale of 1 to 9 was used, in which 5 was the optimum score.

Linespread measurements

The consistency of applesauce was measured objectively by the method of linespread reported by Grawemeyer and Pfund (*15*). Freshly made sauces were cooled to room temperature and linespread was measured graphically on duplicate portions of the sauce.

For measuring the spread of cooked sauces, a diagram of concentric rings, one-eighth of an inch apart, was placed under a piece of plate glass on a surface checked for evenness with a spirit level. A metal band, 1⅜ inches deep and 2 inches in diameter, was first placed on the glass directly over the smallest ring. The cooked sauce was piled into the metal band, leveled off with a straight-edge spatula, and the band carefully removed. The sauce was allowed to spread for 2 minutes, then readings for distance of flow were made at each of four radii. If the sauce spread four-eighths of an inch at one radius, 4 was recorded as the distance of flow at that point. Readings at the four radii were averaged to obtain the linespread of the sauce.

Determination of yields of prepared raw apple and applesauce

Trimming losses and yield of prepared raw apple were determined as the percentage of the apples as purchased. Cooked apples for sauce were sieved by using 75 turns in a household food mill. Weights

JUDGING RECORD FOR RAW APPLES

Name_____ Date_____

For each sample, rate the qualities listed by placing in the proper column the numerical score which best applies

Sample					Sample				
Color of skin:					**Off-flavor:**				
5—Bright, natural red, green, or yellow					5—No off-flavor				
4—Slightly dull					4—Slightly off				
3—Moderately dull					3—Moderately off				
2—Dull					2—Off				
1—Very dull					1—Very objectionable				
Color of flesh:					**Sweetness:**				
5—Natural-greenish, pinkish, or creamy					9—Very undersweet				
4—Slightly dark					8—Undersweet				
3—Moderately dark					7—Moderately under-sweet				
2—Dark					6—Slightly undersweet				
1—Very dark					5—Pleasingly sweet				
Texture of skin:					4—Slightly too sweet				
5—Tender					3—Moderately too sweet				
4—Slightly tough					2—Too sweet				
3—Moderately tough					1—Very sweet				
2—Tough									
1—Very tough									
Texture of flesh:					**Tartness:**				
9—Very firm					9—Very subacid				
8—Too firm					8—Subacid				
7—Moderately too firm					7—Moderately sub-acid				
6—Slightly too firm					6—Slightly subacid				
5—Firm, crisp					5—Pleasingly tart				
4—Slightly mealy					4—Slightly tart				
3—Moderately mealy					3—Moderately tart				
2—Mealy					2—Tart				
1—Very mealy					1—Very tart				
Flavor—Natural:					**General acceptability:**				
5—Natural, full flavor					5—Very good				
4—Slightly weak, undesirable					4—Good				
3—Moderately weak, undesirable					3—Fair				
2—Weak, undesirable					2—Poor				
1—Very weak, undesirable					1—Very poor				

Comments:

JUDGING RECORD FOR APPLESAUCE

Name_____ Date_____

For each sample, rate the qualities listed by placing in the proper column the numerical score which best applies

Sample					Sample				
Color:					**Off-flavor:**				
5—Natural-greenish, creamy, pinkish, yellowish					5—No off-flavor				
4—Slightly dark					4—Slightly off				
3—Moderately dark					3—Moderately off				
2—Dark					2—Off				
1—Very dark					1—Very objectionable				
Translucency:					**Sweetness:**				
5—Lustrous, translucent					9—Very undersweet				
4—Moderately translucent					8—Undersweet				
3—Slightly translucent					7—Moderately undersweet				
2—Cloudy					6—Slightly undersweet				
1—Very cloudy					5—Pleasingly sweet				
					4—Slightly too sweet				
					3—Moderately too sweet				
					2—Too sweet				
					1—Very sweet				
Texture:					**Tartness:**				
9—Very smooth					9—Very subacid				
8—Smooth					8—Subacid				
7—Moderately smooth					7—Moderately subacid				
6—Slightly smooth					6—Slightly subacid				
5—Slightly granular					5—Pleasingly tart				
4—Slightly too granular					4—Slightly tart				
3—Moderately too granular					3—Moderately tart				
2—Granular					2—Tart				
1—Very granular					1—Very tart				
Consistency:					**General acceptability:**				
9—Very thick					5—Very good				
8—Thick					4—Good				
7—Moderately thick					3—Fair				
6—Slightly thick					2—Poor				
5—Thick, so it tends to hold shape					1—Very poor				
4—Slightly too thin									
3—Moderately too thin									
2—Thin									
1—Very thin									
Flavor—Natural:									
5—Natural flavor									
4—Slightly weak									
3—Moderately weak									
2—Weak									
1—Very weak									

Comments:

JUDGING RECORD FOR BAKED APPLES

Name_____ Date_____

For each sample, rate the qualities listed by placing in the proper column the numerical score which best applies

Sample_____					Sample_____				
Wholeness:					**Off-flavor:**				
5—Whole_____					5—No off-flavor_____				
4—Slightly cracked____					4—Slightly off_____				
3—Cracked_____					3—Moderately off_____				
2—Badly cracked_____					2—Off_____				
1—Mushy_____					1—Very objectionable__				
Translucency of flesh:					**Sweetness:**				
5—Lustrous, translucent_____					9—Very undersweet___				
4—Moderately translucent_____					8—Undersweet_____				
3—Slightly translucent					7—Moderately undersweet_____				
2—Cloudy_____					6—Slightly undersweet_				
1—Very cloudy_____					5—Pleasingly sweet____				
Texture of skin:					4—Slightly too sweet___				
5—Tender_____					3—Moderately too sweet_____				
4—Slightly tough_____					2—Too sweet_____				
3—Moderately tough__					1—Very sweet_____				
2—Tough_____									
1—Very tough_____									
Texture of flesh:					**Tartness:**				
9—Very hard_____					9—Very subacid_____				
8—Hard_____					8—Subacid_____				
7—Moderately hard___					7—Moderately subacid_				
6—Slightly hard_____					6—Slightly subacid____				
5—Tender_____					5—Pleasingly tart_____				
4—Slightly soft_____					4—Slightly tart_____				
3—Moderately soft____					3—Moderately tart____				
2—Soft_____					2—Tart_____				
1—Very soft_____					1—Very tart_____				
Flavor—Natural:					**General acceptability:**				
5—Natural, full flavor_					5—Very good_____				
4—Slightly weak_____					4—Good_____				
3—Moderately weak__					3—Fair_____				
2—Weak_____					2—Poor_____				
1—Very weak_____					1—Very poor_____				

Comments:

were determined for the cooked apple, for the pulp remaining in the mill, and for the strained sauce. Pulp remaining in the mill was designated as unsieved pulp and considered as waste. Percentage of unsieved pulp was calculated on the basis of prepared raw apple; percentage yields of sieved and unsieved sauces were calculated on the basis of prepared raw apple plus water used in cooking the sauces.

Statistical methods

An analysis of variance was applied to each palatability characteristic to determine the significance of differences due to variety of apple, length of storage time, storage temperature, maturity, and crop year. For the first year's scores, analyses were calculated both including and excluding scores for unstored apples. This was done because the figures for the unstored sample were the same whether apples were subsequently stored at 32° or at 40° F., which might mask the effect due to storage period or to temperature of storage.

Analysis of variance was used also to test the significance of differences in palatability of sauce due to the length of time the sauce was cooked, and to determine the significance of differences in certain chemical constituents due to variety, storage temperature, and storage period.

Correlation coefficients were computed to determine relationships among quality characteristics of raw and cooked apples, as measured by different methods.

RESULTS AND DISCUSSION

Weight loss and gross deterioration of apples in storage

In household use of apples weight loss, rot, shriveling, and softening are important considerations. Loss in weight determined on the second year's crop occurred in all varieties throughout storage for 3, 5, and 7 months (table 1). As might be expected, it was greater for apples stored at 40° F. in a room without humidity control than at 32° with 85 to 90 percent relative humidity. It differed among varieties, but for any given variety the rate of loss was fairly uniform throughout storage. Delicious and Rome Beauty lost relatively least weight after 3 months as well as after 7 months. Golden Delicious, which lost most weight in relation to the unstored sample by the end of 3 months, also lost most weight during 7 months of storage. Mature apples of the Delicious, Golden Delicious, and Rome Beauty varieties lost weight to a greater degree than the immature. However, immature apples of the Stayman variety showed greater weight loss than the mature at each storage period.

Also, as might be expected, there was less deterioration of apples in storage at 32° than at 40° F., as shown by the lower percentages of rot, softening, and shriveling at the lower temperature. Of the mature apples, Delicious and Rome Beauty were in the best condition after 7 months of storage at both temperatures. At 32° Delicious showed no rot, no softening to hand pressure, and very little shriveling. Rome Beauty developed a negligible amount of shriveling and softening and little rot. Greater deterioration in the other varieties may

TABLE 1.—*Weight loss, rot, softening, and shriveling of apples during storage* [1]

Variety and storage temperature	Storage time	Mature apples				Immature apples			
		Weight loss [2]	Rot [3]	Softening [3]	Shriveling [3]	Weight loss [2]	Rot [3]	Softening [3]	Shriveling [3]
	Months	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Delicious:									
32° F.	0	0	0	0	0	0	0	0	0
	3	2.4	0	0	0	1.5	0	0	0
	5	4.2	0	0	0	3.7	0	0	0
	7	5.3	0	0	2.9	4.8	.6	.6	3.1
40° F.	0	0	0	0	0	0	0	0	0
	3	3.7	1.4	0	0	2.9	0	0	0
	5	5.1	5.1	1.7	0	4.4	1.6	0	0
	7	6.5	3.8	6.1	4.5	5.8	1.7	.9	8.6
Golden Delicious:									
32° F.	0	0	0	0	0	0	0	0	0
	3	5.7	1.9	5.8	5.8	4.0	0	0	0
	5	9.7	18.4	17.5	39.5	6.6	2.8	4.7	21.5
	7	12.9	11.2	40.8	78.6	8.8	5.7	19.1	81.9
40° F.	0	0	0	0	0	0	0	0	0
	3	7.7	7.4	4.6	6.5	6.7	11.9	1.7	2.5
	5	11.7	19.0	22.3	57.9	9.7	9.0	5.4	16.2
	7	16.1	28.3	37.2	64.9	12.4	15.4	23.6	59.1
Jonathan:									
32° F.	0	0	0	0	0	------	------	------	------
	3	3.4	2.6	8.8	5.3	------	------	------	------
	5	4.9	1.0	2.9	12.7	------	------	------	------
	7	6.6	1.4	2.2	31.7	------	------	------	------
40° F.	0	0	0	0	0	------	------	------	------
	3	4.6	3.0	15.9	14.4	------	------	------	------
	5	6.6	4.4	14.6	25.6	------	------	------	------
	7	8.3	14.5	7.3	49.3	------	------	------	------
Rome Beauty:									
32° F.	0	0	0	0	0	0	0	0	0
	3	2.5	0	0	0	1.7	1.0	0	0
	5	3.6	2.3	1.2	1.1	3.0	1.2	0	1.2
	7	5.2	7.4	0	0	4.2	0	0	0
40° F.	0	0	0	0	0	0	0	0	0
	3	2.9	0	0	0	2.3	0	0	0
	5	4.4	5.7	0	2.9	3.6	1.1	0	2.2
	7	5.8	16.8	2.4	13.6	5.2	3.4	.7	10.3
Stayman:									
32° F.	0	0	0	0	0	0	0	0	0
	3	5.1	6.4	2.2	0	5.4	2.4	4.7	0
	5	6.8	9.5	2.4	13.1	7.8	4.4	4.4	10.0
	7	8.9	4.7	5.9	25.9	10.0	2.2	18.9	44.4
40° F.	0	0	0	0	0	0	0	0	0
	3	5.8	5.3	5.3	8.4	6.3	5.3	7.5	3.2
	5	7.3	11.6	10.5	26.3	8.7	11.4	9.4	21.9
	7	9.4	16.2	27.9	48.1	11.3	13.5	28.7	48.5

[1] 1949 crop only.

[2] Data from a sample of 22 to 28 apples.

[3] Based on deterioration in 1 bushel apples: Minimum rot, ¼ apple; minimum softening, ½ apple; minimum shriveling, ½ apple.

be accounted for by delay between picking and storage or late picking and storage of the apples.

In the first year, although data are not presented, similar trends in deterioration were observed for Delicious, Rome Beauty, and Stayman varieties. Golden Delicious apples were picked and stored earlier in the season than in the second year, so were of better quality. Although they showed the least rot, they did have moderate softening and considerable shriveling. Jonathan and Winesap were in poor condition at the beginning and showed the most rot at each storage interval. Softening and shriveling were also appreciable in these two varieties.

The immature apples of the Golden Delicious and Rome Beauty varieties kept better than the mature apples of these varieties. Deterioration in immature Delicious was slight, about the same degree as in the mature, except for higher shriveling in the immature lots stored at 40° F. for 7 months. Immature Stayman after 3 months had less rot and more shriveling than mature, and at 40° storage, showed less rot after 7 months, but the amount of softening and shriveling was about the same in both immature and mature.

These results reemphasize the need for picking at the proper time and storing promptly under optimum conditions to obtain high quality in apples.

Histological observations

Gross Structure of the Apple

The principal parts of the apple, as described by Tukey and Young (*46*) and as illustrated in figure 1 are skin, consisting of epidermis and hypodermis; cortex; and core, consisting of pith, fleshy pericarp, and cartilaginous pericarp.

The skin contains deposits of cutin, waxes, and suberin (cork) variously distributed to form a waterproofing coat. The cortex, pith, and fleshy pericarp are composed predominantly of parenchyma, or large, thin-walled, undifferentiated type cells, and make up the fleshy portion of the apple, with cortex the dominant portion by volume.

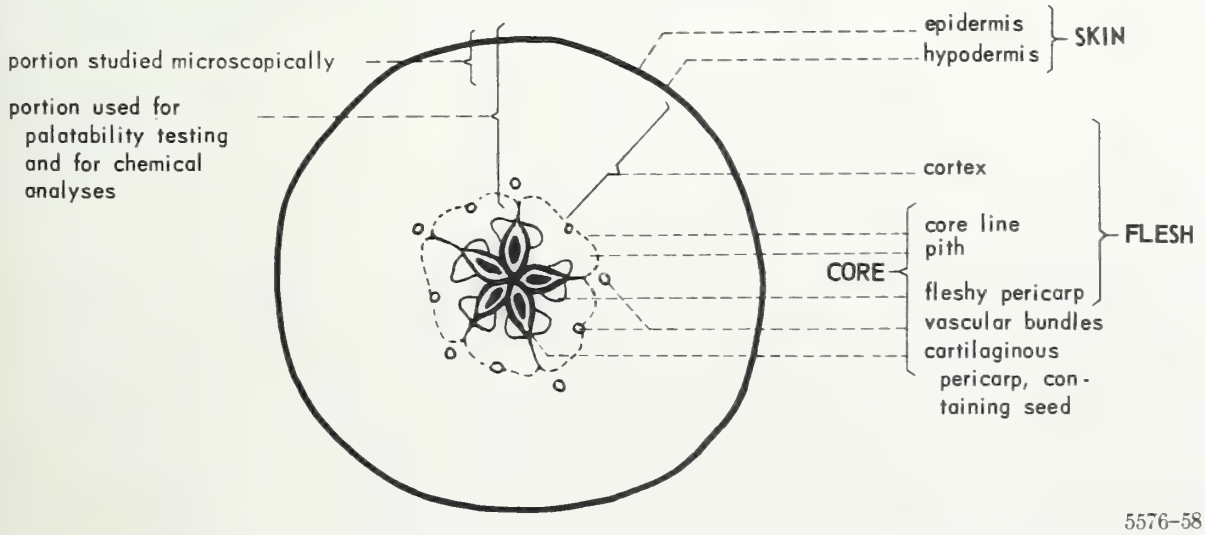


FIGURE 1.—Schematic drawing of cross section of an apple.

Each segment used for histological study included skin and cortex to a depth of 3 or 4 mm.

A highly magnified segment of skin and cortex, drawn to illustrate the various cells and structures studied in apples, is shown in figure 2.

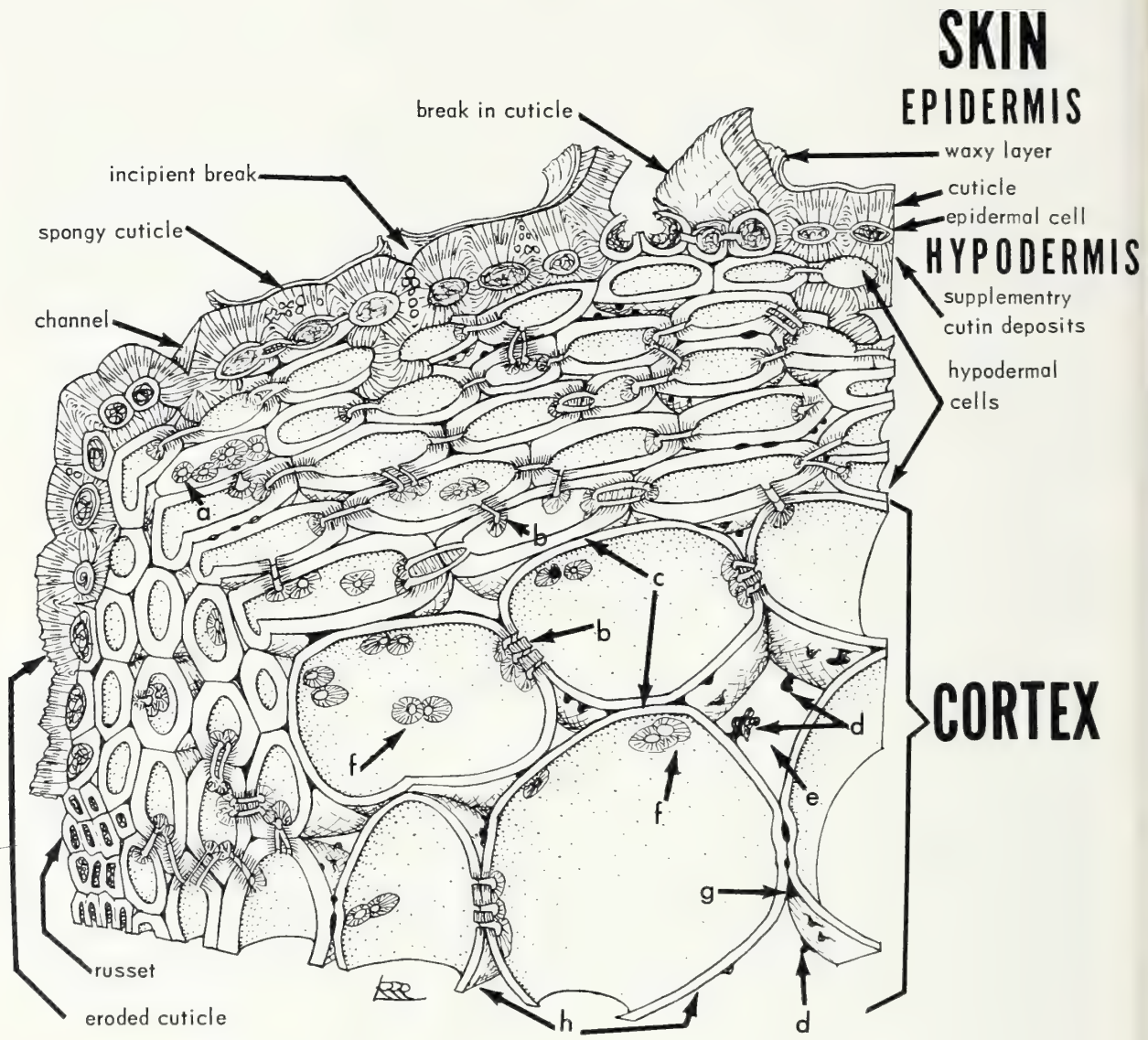


FIGURE 2.—A composite drawing illustrating apple skin and a shallow portion of cortex.

The Skin

Epidermis and waterproofing layers.—The epidermis or outermost zone is a single cell layer in thickness. As seen in sections, the epidermal cells of all apple varieties studied appeared to be of uniform size and shape, but the epidermis varied in other ways, as shown in table 2 and in plates 1, 2, and 3.

Cutin occurring in the outer walls of the epidermal cells forms the waterproofing layer called cuticle (*11*) (fig. 2). Further waterproofing is provided by a waxy layer external to the cutin (*26*, *27*).

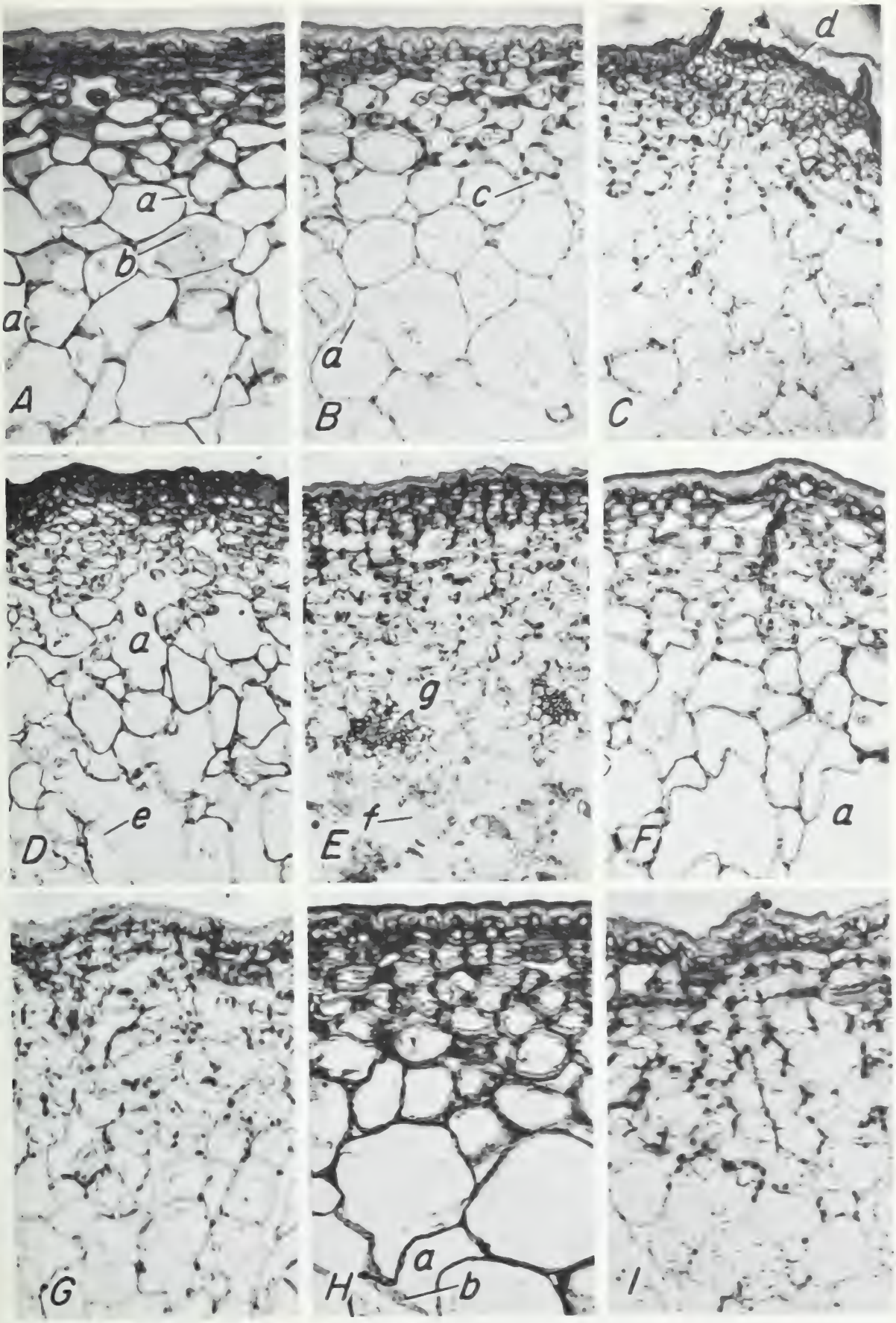
TABLE 2.—*Histological characteristics of the waterproofing layers of apples* [1]

Variety	Cuticle						Supplementary cutin deposits [2]			
	Thickness		Surface interruptions			Spongy areas (estimated)	Between epidermal cells	Between hypodermal cells		
	Range	Average	Apples showing russet	Breaks per field (100 ×)	Channels per field (100 ×)			First cell layer	Second cell layer	Third cell layer
	Microns	*Microns*	*Percent*	*Average number*	*Average number*					
Delicious	8–20	15. 4	20	0. 3	3. 2	Rare	††	†††	††	†
Golden Delicious	10–20	16. 1	80	3. 3	6. 2	Numerous	†	††	†	0
Jonathan	10–20	14. 0	40	1. 6	6. 0	None	0	0	0	0
Rome Beauty	12–24	18. 1	33	. 5	4. 0	Rare	†††	†	0	0
Stayman	12–30	17. 5	50	1. 3	4. 7	Frequent	††	†	0	0

[1] Data for russet based on macroscopic observations on 6 apples from each storage lot (42 Jonathan, 84 of each other variety); other data based on microscopic observations on one apple from each storage lot (7 Jonathan, 14 of each other variety); sections from 3 locations on each apple. Maturities, storage times, storage temperatures, and raw and steamed conditions combined for one crop year (1949).

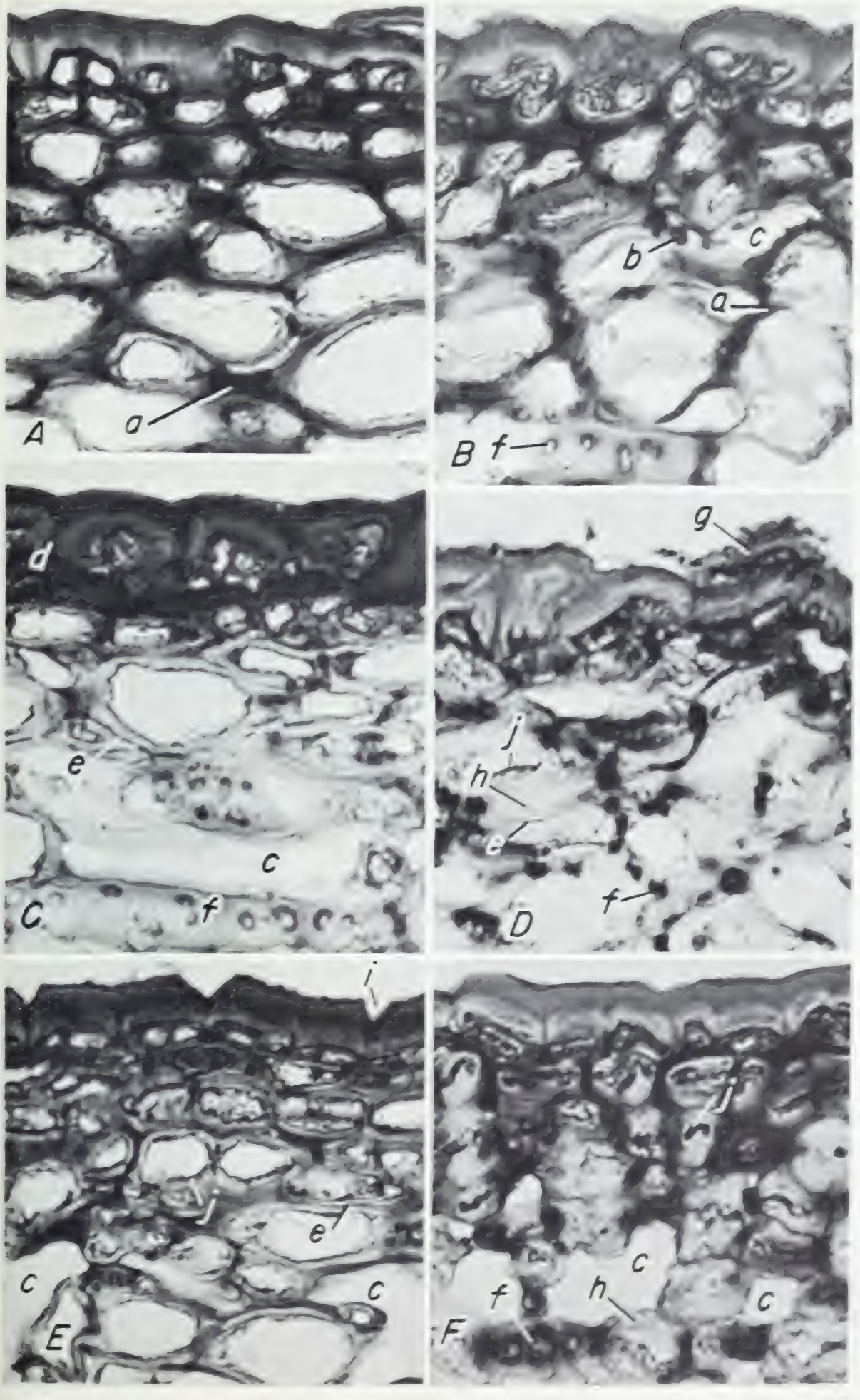
[2] Key to rating: †††, prevalent; ††, frequent; †, infrequent; 0, rare or none.

Photomicrographs of cross sections of raw and steamed apple tissues illustrating variations in structure of skin and cortex and changes caused by cooking. *A*, Delicious raw; *B*, Delicious steamed for 15 minutes; *C*, Golden Delicious steamed for 45 minutes; *D*, Jonathan raw; *E*, Jonathan steamed for 45 minutes; *F*, Rome Beauty raw; *G*, Rome Beauty steamed for 45 minutes; *H*, Stayman raw; *I*, Stayman steamed for 45 minutes. *a*, Intercellular space; *b*, pit areas or nodules; *c*, nodules; *d*, suberized area; *e*, ruptured cell wall; *f*, fragmented cell wall; *g*, fibrovascular bundle. × 88.



BN-7749

Photomicrographs of cross sections of raw and steamed apple skins, illustrating variations in structure of cuticle and hypodermal cell walls and changes caused by cooking. *A*, Delicious raw; *B*, Delicious steamed for 45 minutes; *C*, Golden Delicious raw; *D*, Golden Delicious steamed for 45 minutes; *E*, Jonathan raw; *F*, Jonathan steamed for 45 minutes. *a*, Junctural mass of pectic material; *b*, nodule; *c*, intercellular space; *d*, supplementary cutin deposit; *e*, middle lamella; *f*, pit and pit area; *g*, eroded cuticle; *h*, spongy cell wall; *i*, channel in cuticle; *j*, cell content. × 385.



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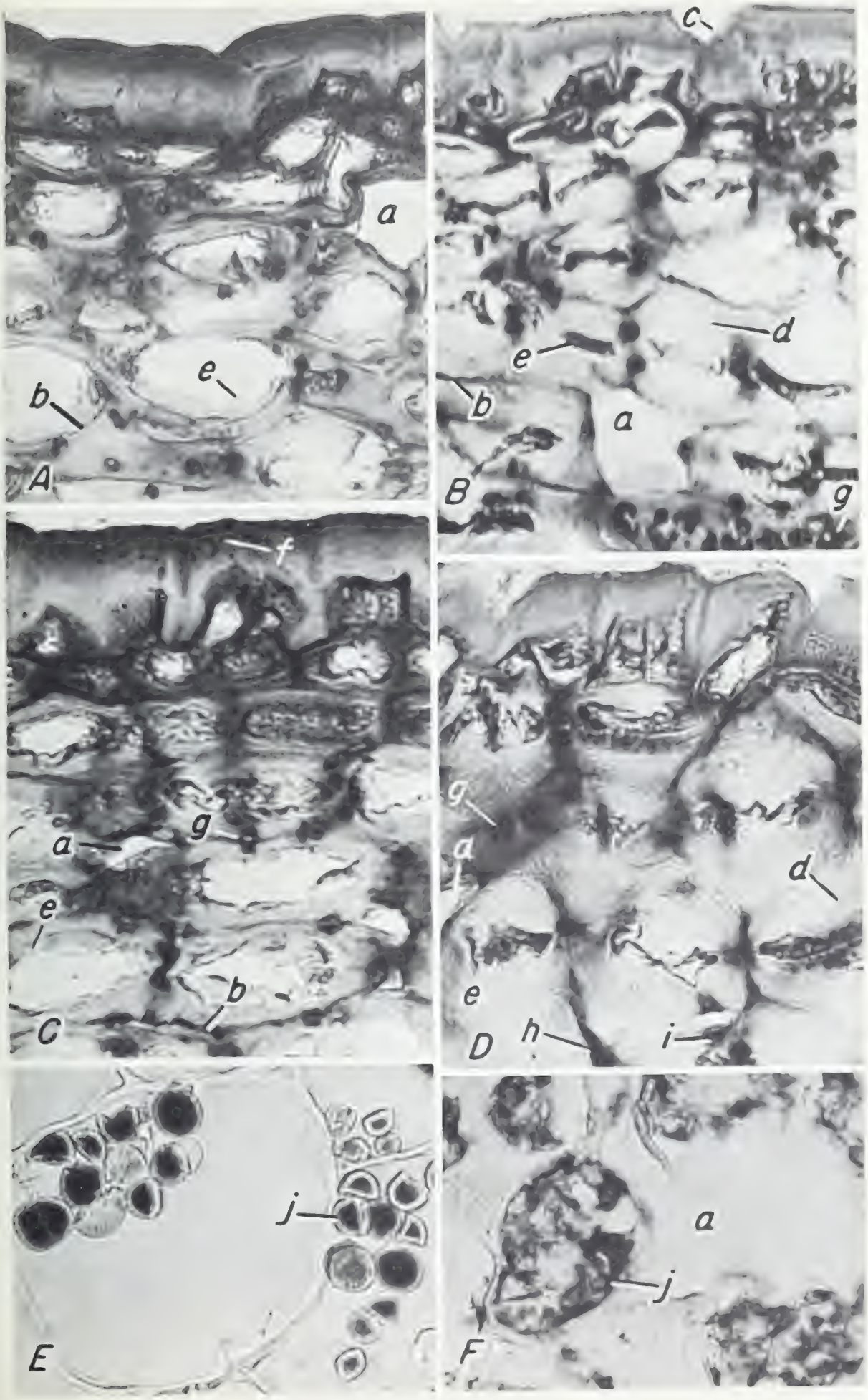
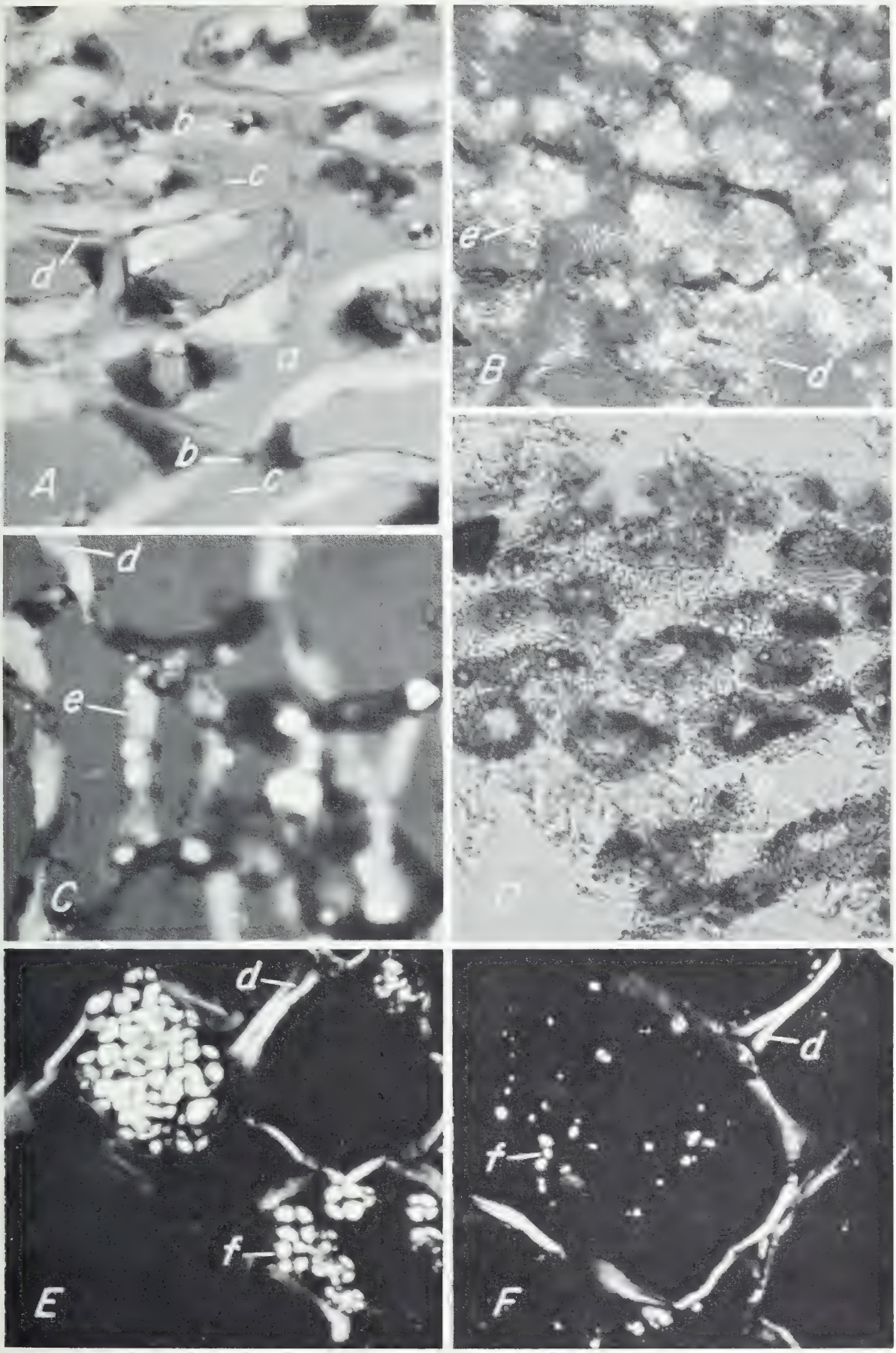
Photomicrographs of cross sections of raw and steamed apple skins, illustrating variations in structure of cuticle and hypodermal cell walls and changes caused by cooking. *A*, Rome Beauty raw; *B*, Rome Beauty steamed for 45 minutes; *C*, Stayman raw; *D*, Stayman steamed for 45 minutes; *E* and *F*, photomicrographs of cortex cells from Delicious apple, unstored sample, raw and boiled for 8 minutes, stained with iodine, showing starch in granules (raw) and in gelatinized condition (cooked). *a*, Intercellular space; *b*, middle lamella; *c*, channel in cuticle; *d*, spongy cell wall; *e*, cell contents; *f*, spongy cuticle; *g*, pit area; *h*, junctural mass of pectic material; *i*, separated pit area; *j*, starch. × 385.



BS-7747

Photomicrographs of hypodermal and cortical cells, before and after cooking. All except *D* were made with polarized light. *A*, Rome Beauty raw, hypodermis treated with ammonium oxalate, tested for cellulose with iodine and zinc chloride; *B*, Rome Beauty steamed for 45 minutes, hypodermis treated with ammonium oxalate, stained with ruthenium red; *C*, Rome Beauty steamed for 45 minutes, borderline cells between hypodermis and cortex, treated as in figure *A; D*, Golden Delicious steamed for 45 minutes, hypodermis treated with 4 percent sodium hydroxide and tested for cellulose with iodine and sulfuric acid, as seen in brightfield illumination; *E*, Delicious unstored sample raw, cortex cells containing starch grains; *F*, Delicious unstored sample boiled for 8 minutes, cortex cells containing starch grains. *a*, Intercellular space; *b*, pit area; *c*, brown-stained pellicle seen surrounding cells after removal of pectins; *d*, middle lamella; *e*, cell walls showing flaky breakdown; *f*, starch. × 345.



BN-7746

Cuticle thickness, determined for all samples, was found to range from 8 to 30 microns (table 2). Stayman apple cuticle had the greatest range (12 to 30 microns), that from Delicious and Rome Beauty apples the next greatest (8 to 20 and 12 to 24 microns), and that from Golden Delicious and Jonathan apples somewhat less (10 to 20 microns). When cuticle measurements were averaged by variety, the highest average (18.1 microns for Rome Beauty) was only 4.1 microns greater than the lowest (14.0 microns for Jonathan). Measurements for Stayman, Golden Delicious, and Delicious intervened in decreasing order.

Cuticle from stored samples averaged slightly thicker than that from unstored samples. No other differences between the two lots of samples were observed.

As has been shown (*5*, *6*, *30*, *45*), many varieties of apples are subject to cracking and replacement of some of the cuticle by suberized (corky) areas called russet. Although cork is usually classified as a waterproof tissue, it was reported (*34*) that the presence of these corky areas on apples means a lowered water retention capacity in the skin. In this study, interruptions in the surface of the cuticle occurred in the form of breaks, slits or channels, and eroded areas as well as russet (fig. 2, table 2). Internal interruptions in the cuticle were also observed in the form of spongy areas and cavitylike structures. Channels were common in all varieties. The cuticle of Golden Delicious apples (pls. 1, *C;* 2, *D*) was most subject to russet and other surface interruptions, and was most spongy or least homogeneous internally. Jonathan apples were intermediate in the amount of russet; Jonathan cuticle was the least spongy internally but had numerous slits or channels (pls. 1, *D*, *E;* 2, *E*). Cuticle of Delicious and Rome Beauty apples (pls. 1, *A*, *B*, *F*, *G;* 2, *A*, *B;* 3, *A*, *B*) had the smoothest or the least interrupted exterior surface of all and was more homogeneous internally than that of Golden Delicious apples. Stayman apples were high in russet and sponginess and intermediate in the number of surface interruptions in the cuticle (pls. 1, *H*, *I;* 3, *C*, *D*).

Supplementary cutin deposits were observed in the walls between the epidermal and hypodermal cells of all the varieties except Jonathan. They were confined to walls between epidermal cells in Rome Beauty apples, while in Stayman, Golden Delicious, and Delicious apples they occurred in walls of the hypodermis, 1-, 2-, and 3-cell layers deep. These deposits may have been a factor involved in toughness of skin, in determining storage life of the apples, and in adherence of skin to flesh in baked apples.

The cuticle was colorless in sections stained with ruthenium red, except for pink veins and films extending horizontally near the outer walls of the epidermal cells, and radially toward the surface; these pink structures possibly represent concentrations of pectic materials.

When stained by the diphenylene diamine acetate procedure, the cuticle was seen to consist of an outer and an inner zone of dark and light olive to tan color, respectively (pls. 2, *A*, *C*, *E;* 3, *A*, *C*); the veins and films were dark brown. The cuticle usually appeared layered or striated or both in these preparations.

After having been steamed, the cuticle showed reduced capacity to stain with diphenylene diamine acetate, especially in the outer zone (pls. 1, *B*, *E*, *G*, *I;* 2, *D*, *F;* 3, *B*, *D*). The cuticle of the Rome Beauty variety showed an increase in the number of channels (pl. 3, *B*). No other alterations were noted attributable to cooking.

Slides from Delicious and Stayman apples were treated with cuprammonium hydroxide to remove cellulose and were stained with iodine. After this treatment the outer zone of the cuticle contained numerous horizontal brown-lined tubules not seen in sections receiving other treatments.

In polarized light the cuticle was moderately to weakly birefringent (doubly refractive). Birefringence was usually strongest in the inner zone and weak or lacking in the outer zone. Variations in this respect did not appear to be closely related to variety, maturity, storage conditions, or steaming.

The hypodermis.—The hypodermis (fig. 2) is a region from 4 to 10 cells thick just inside the epidermis. The cells are larger than those of the epidermis and gradually increase in size toward the cortex. The walls are thickened and contain only irregular deposits of cutin. The walls become thinner toward the cortex. The apple varieties studied fell into two groups with regard to depth of hypodermis, size of its cells, and thickness of its cell walls (table 3). In Stayman and Rome Beauty apples the hypodermis extended to the greatest depth, and its cells were the largest and had the thickest walls (pls. 1, *F*, *H;* 3, *A*, *C*). The hypodermis of Golden Delicious (pl. 2, *C*), Jonathan (pls. 1, *D;* 2, *E*), and Delicious apples (pls. 1, *A;* 2, *A*) was shallow and consisted of smaller, less thick-walled cells.

Structures that stained with ruthenium red were often prominent in the hypodermis. They were middle lamella, extracellular sheath and nodules, intercellular junctural masses, and circles or crescents (bright-colored areas surrounding pits) (*44*). They were least prominent where cell walls as a whole were intensely stained and most prominent (by contrast) where lightly stained. Structures staining with ruthenium red are referred to as "pectic structures," while keeping in mind the likelihood that they contain other substances also. Among the unstored samples, the hypodermis of Golden Delicious and Stayman apples had the most prominent pectic structures. In the hypodermis of Delicious unstored samples the overall stain was most intense and the pectic structures were not evident; after 7 months' storage they were evident though not prominent. Rome Beauty and Jonathan apples had pectic structures of medium prominence at first; after storage their pectic structures were more prominent, and after 7 months they resembled more nearly those of Golden Delicious and Stayman. These same structures were colored brown by diphenylene diamine acetate (pls. 3, 4), which stains pentosans as well as cutin (*14*). Nodules and junctural masses also sometimes appeared bright red when stained with Congo red and Sudan IV.

When examined in sections with polarized light, the hypodermal walls were moderately and uniformly birefringent and faintly laminate (pl. 4, *A*). In surface view they were less strongly birefringent and, where not interrupted by pits, often exhibited a faint pattern of crisscross striations resembling threads in a woven cloth.

When cellulose tests were applied to deparaffinized sections, cell walls were blue; in some a delicate brown film was seen in the region of the extracellular sheath (pl. 4, *A*). When sections were treated with cuprammonium hydroxide, the cellulose was removed, leaving a cellular framework that stained with ruthenium red. Treatment of sections of raw-fixed or steamed-fixed material with hot dilute sodium hydroxide removed all ruthenium-red-staining substances and left a cellular framework which gave a strong cellulose reaction. Treat-

TABLE 3.—*Histological characteristics of the hypodermis from raw and steamed apples* [1]

Variety	Depth of hypodermis					Radial diameter of cells (range)		Thickness of cell walls [2] (range)			Flaky breakdown, occurrence in steamed tissue	
	Cell layers	Raw		Steamed for 45 minutes		Raw	Steamed for 45 minutes	Raw	Steamed for 45 minutes	Increase during steaming		
		Range	Average	Range	Average							
	Number	*Microns*	*Microns*	*Microns*	*Microns*	*Microns*	*Microns*	*Microns*	*Microns*	*Microns*	*Percent*	
Delicious	4– 7	80–150	120	100–180	122	16–30	17–28	5– 9	9–18	4– 9	15	Mostly in immature samples; more at 40° than at 32° F.
Golden Delicious	4– 8	90–130	100	80–140	103	15–22	16–25	6–10	13–18	7– 8	31	Mostly in mature samples; more at 40°.
Jonathan	5– 7	110–140	123	105–160	125	18–28	15–30	5– 9	18–22	11–13	46	Mature samples only; more at 40°.
Rome Beauty	4– 9	110–200	160	120–280	210	20–32	25–37	6–12	11–26	5–14	31	None in immature samples (all in mature); storage temperatures equal.
Stayman	4–10	160–280	200	180–280	240	22–44	25–46	9–15	18–35	9–20	36	Mostly in immature samples; storage temperatures equal.

[1] From 14 samples of each variety except Jonathan, of which 7 samples were used. Maturities, storage times, and storage temperatures were combined for one crop year (1949).

[2] Measurements of cells in middle portion of hypodermis.

ment with ammonium oxalate, or with hot dilute ammonium oxalate and ammonia together, or with hot dilute hydrochloric acid, or with hot water, failed to remove all ruthenium-red-staining substances. Some of the latter reagents are said to be specific for pectins and others for hemicelluloses (*29*). Considering these results together with staining reactions it is concluded that pectins and hemicelluloses occur in close association in cell walls and in the so-called pectic structures.

In material fixed after steaming, the hypodermis extended to a greater depth, especially in Rome Beauty and Stayman apples (pl. 1, *G*, *I*). Cell walls of all varieties were less intensely and less uniformly stained (pls. 2, *D*, *F*; 3, *B*, *D*), the middle lamellae paler, and the other pectic structures more prominent. Cell walls were also usually swollen and often spongy in appearance. The middle lamellae and cell walls thus both appeared weakened. The hypodermis of Delicious apples retained greater staining capacity in both wall and middle lamella than did the other varieties. Delicious samples showed the least swelling of hypodermal cell walls, and Jonathan the most, although the greatest thickness was attained in Stayman samples. Except for the Jonathan variety (previously described as bruised when received), no additional separation of hypodermal cells was observed in steamed samples.

In many slides made from steamed specimens, the spongy cell walls when examined with polarized light showed a change of structure here termed "flaky breakdown" (pl. 4, *B*, *C*). Within the walls there appeared highly birefringent bodies that were distinct in color and other respects from the moderately birefringent cellulose of unaltered cell walls. The bodies or "flakes" looked most like partially gelatinized starch granules (pl. 4, *F*). They reacted negatively to the iodine test for starch and to the tests used for pectins and pentosans. Their appearance in polarized light indicated the presence of cellulose. They were not created in deparaffinized sections of uncooked apples by treatment with hot water or with fluids applied for extracting pectins or hemicelluloses. The possibility is suggested that the cellulose component of apple hypodermal cell walls can be altered by steaming, a possibility also suggested by Simpson and Halliday for the cellulose of carrot parenchyma (*39*), although from different evidence.

Flaky breakdown appeared to occur first in that part of the wall nearest the middle lamella, but often the entire wall except for the areas surrounding the pits was involved. It occurred sometimes only at the edges of the sections (which circumstance points to the possibility of an oxidative or enzymatic reaction as a part of the cause), sometimes in the entire hypodermal segment of the sections. It was seen in sections of some steamed-fixed samples of all varieties but was not always present in any one variety. It was least common and extensive in hypodermis from Delicious apples and most prominent and extensive in hypodermis from Stayman and Golden Delicious apples. A few birefringent bodies of apparently similar nature were observed in the cell walls and middle lamellae of some stored samples that had been fixed without steaming.

The Cortex

Apple cortex (fig. 2) is composed of large, thin-walled, loosely arranged parenchyma cells with sparse vascular bundles scattered

throughout. The pectic structures were similar to those of the hypodermis, except they were usually smaller and fewer. Cell walls appeared to be similar in composition to those of the hypodermis. When examined in sectional view in polarized light the walls were highly birefringent (pl. 4, *E*), whereas in surface view they were only weakly birefringent and showed faint crisscross striations and prominent pits.

Varietal differences in the cortex, some of which are listed in table 4, were small. A microscopic survey of slices cleared in the manner

TABLE 4.—*Histological characteristics of the cortex from raw and steamed apples*

Variety	Size of cells,[1] raw			Characters of cell walls		
	Length and width		Cross sectional area [2]	Thickness, raw or steamed		Flaky breakdown occurrence in 14 steamed samples [3]
	Range	Average		Range	Average	
	Microns	*Microns*	*Sq. μ × 0.01*	*Microns*	*Microns*	*Number*
Delicious	172 – 344 × 129 – 241	260 × 180	368	0. 9–3. 5	1. 8	6
Golden Delicious	198 – 456 × 129 – 258	290 × 170	387	. 9–2. 6	1. 7	10
Jonathan	129 – 413 × 129 – 258	280 × 175	385	. 9–2. 2	1. 6	6
Rome Beauty	138 – 671 × 69 – 215	270 × 150	318	1. 3–4. 4	2. 0	12
Stayman	215 – 430 × 172 – 301	325 × 250	638	. 9–3. 5	2. 2	8

[1] Measurements of isolated cells in crush mounts of raw-fixed samples for one crop year (1949).

[2] Long radius multiplied by short radius, multiplied by 3.1416.

[3] These occurrences are all minor as compared to major occurrences in hypodermal cells.

described by Kraus (*18*) revealed similarity in number and size of vascular bundles. This confirms the findings of Kraus for four of these varieties, Jonathan, Delicious, Rome Beauty, and Stayman. Of the unstored samples, more starch granules (pl. 4, *E*) were observed in the cortex cells of Delicious and Stayman apples than in the other varieties. After 3 months of storage no variety contained appreciable amounts of starch. Rome Beauty apples had smaller and Stayman apples larger cells in this portion of the cortex than did the other varieties. Average thickness of the cell walls was least in Jonathan apples, and greater in Golden Delicious, Delicious, Rome Beauty, and Stayman apples, in that order. However, because of difficulties in making these measurements, it is doubtful that any significance can be attached to these differences.

Other characters of the cell walls that showed slight varietal differences were intensity of stain, extent of rupture or fragmentation, and the rare occurrence of birefringent bodies suggesting flaky breakdown. Delicious and Rome Beauty had the greatest general staining capacity (least prominent pits), the least rupture, and no observed

birefringent bodies. Jonathan, Stayman, and Golden Delicious had lesser staining capacity (more prominent pits), greater extent of rupture, and several observed examples of birefringent bodies.

After prolonged storage, the tissues showed a reduced staining capacity and a greater incidence of ruptured cell walls in sections. Cell wall thickness apparently did not change during storage, according to the measurements.

In sections of tissues that had been steamed before fixing, starch, if present, was found in a partially or wholly gelatinized condition (pls. 3, *F;* 4, *F*). Cell walls and middle lamellae were paler, other pectic structures were more prominent, cell wall rupture was generally more extensive (pl. 1, *B, C, E, G, I*), and birefringent bodies or "flakes" were more frequent. Flakes of the cortex were usually larger than those of the hypodermis, they occurred singly, and many seemed to be in the middle lamella; they may not all be of the same origin as those of the hypodermis. Cell wall thickness apparently did not change according to the measurements. The cortex of Delicious apples retained the greatest staining capacity, showed the fewest instances of flaky breakdown, and had little or no increase in ruptured cell walls. Golden Delicious, Rome Beauty, and Stayman samples had relatively more instances of flaky breakdown in the cortex. Separation of cortex cells due to cooking was not observed in the sections. When sections were treated with histochemical reagents, cortex cell walls reacted similarly to hypodermal cell walls.

Chemical findings

Results of analyses for total acidity, pH, reducing sugar, total sugar, total pectin, pectic acid, and moisture content are given for raw apples by crop year and maturity, and before and after storage (tables 5 and 6). Results of analysis of variance for the various chemical constituents are given in table 7. Correlation coefficients between the chemical constituents of mature apples are presented in table 8.

Total Acidity

The six varieties of mature apples included in this study differed significantly in total titratable acidity. As shown in figure 3, before storage of apples, Stayman had the highest value of 91 ml. of N/10 sodium hydroxide required to neutralize the acid; Jonathan had a value of 84, Winesap 72, Golden Delicious 57, Rome Beauty 44, and Delicious 19. Storage caused a significant decrease in total acidity of the apples. After 7 months at 40° F. total acidity values of the varieties ranged from 65 to 14 with Stayman, highest and Delicious, lowest. Total acidity of apples stored at 40° was not significantly different from that of apples stored at 32°. The decrease in total acidity of apples during storage agrees with earlier reports of Magness and associates (*25*) and Vecher and Bukin (*49*). In the latter report it was stated that a decrease in total acidity was caused by oxidation in the normal respiration of the fruit.

Total acidity of immature apples like mature apples showed significant differences related to variety and storage time. Of the four varieties of immature apples studied, Stayman was highest, with values of 88 before storage to 60 after storage for 7 months at 40° F. and Delicious lowest, with a value of 23 which decreased to 8 after 5

TABLE 5.—RAW APPLES: *Acidity and sugar content before and after storage of apples, by crop year* [1]

Variety of apple and storage temperature	Storage time	Total acidity [2]			pH [3]			Reducing sugar [4]			Total sugar [4]	
		Mature apples		Immature apples	Mature apples		Immature apples	Mature apples		Immature apples	Mature apples, second crop year	Immature apples
		First crop year	Second crop year		First crop year	Second crop year		First crop year	Second crop year			
Delicious:	*Months*	*Ml.*	*Ml.*	*Ml.*				*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
32° F.	0	----	19	23	4.0	4.2	4.1	59	41	41	56	54
	3	30	17	13	4.3	4.2	4.5	53	49	50	62	61
	5	26	15	8	4.3	5.0	5.3	54	52	51	62	62
	7	20	13	10	4.6	4.7	4.9	56	52	55	59	58
40° F.	0	----	19	23	4.0	4.2	4.1	59	41	41	56	54
	3	21	15	19	4.4	4.3	4.2	56	54	55	64	60
	5	20	10	8	4.4	4.9	4.8	52	56	54	64	61
	7	19	10	10	4.4	4.5	4.5	59	57	53	63	55
Golden Delicious:												
32° F.	0	----	57	66	3.5	3.6	3.6	49	40	42	62	55
	3	45	48	44	3.8	3.7	3.9	49	41	44	58	62
	5	24	26	39	4.2	4.5	4.0	50	46	44	61	61
	7	16	21	33	4.5	4.6	4.3	46	48	46	60	59
40° F.	0	----	57	66	3.5	3.6	3.6	49	40	42	62	55
	3	40	41	45	3.9	3.8	3.7	46	42	46	61	62
	5	25	30	30	4.3	4.2	4.1	49	48	45	64	61
	7	21	30	30	4.5	4.4	4.1	48	48	49	60	56
Jonathan:												
32° F.	0	89	80	----	3.5	3.4	----	37	41	----	61	----
	3	72	79	----	3.5	3.5	----	49	43	----	57	----
	5	50	62	----	3.8	3.8	----	49	48	----	61	----
	7	53	57	----	3.8	3.6	----	45	49	----	59	----

40° F	0	89	80	--------	3.5	3.4	--------	37	42	--------	61	--------
	3	56	70	--------	3.6	3.6	--------	48	44	--------	59	--------
	5	50	63	--------	3.8	3.6	--------	47	49	--------	59	--------
	7	53	70	--------	3.8	4.0	--------	46	49	--------	59	--------
Rome Beauty:												
32° F	0	38	49	53	3.5	3.5	3.5	41	35	38	54	50
	3	35	42	35	3.7	3.7	3.4	41	40	43	57	56
	5	28	30	33	3.7	3.8	3.9	46	41	43	56	54
	7	25	25	30	4.0	4.2	3.8	45	40	43	48	58
40° F	0	38	49	53	3.5	3.5	3.5	41	35	38	54	50
	3	40	34	35	3.8	3.9	3.7	44	41	44	54	57
	5	26	27	25	3.9	4.1	4.0	44	42	46	56	57
	7	22	25	15	4.0	4.2	4.2	45	41	46	55	50
Stayman:												
32° F	0	94	88	88	3.3	3.3	3.4	33	35	34	56	51
	3	90	82	78	3.5	3.6	3.4	37	40	37	59	61
	5	73	79	67	3.6	3.6	3.7	45	41	39	57	60
	7	68	75	68	3.6	3.7	3.6	42	41	43	58	60
40° F	0	94	88	88	3.3	3.3	3.4	33	35	34	56	51
	3	84	68	70	3.4	3.7	3.4	39	42	39	61	61
	5	80	70	65	3.6	3.7	3.6	45	44	44	61	61
	7	66	64	60	3.7	3.8	3.8	40	47	48	60	62
Winesap:												
32° F	0	72	--------	--------	3.6	--------	--------	44	--------	--------	--------	--------
	3	66	--------	--------	3.6	--------	--------	42	--------	--------	--------	--------
	5	68	--------	--------	3.7	--------	--------	42	--------	--------	--------	--------
	7	58	--------	--------	3.9	--------	--------	42	--------	--------	--------	--------
40° F	0	72	--------	--------	3.6	--------	--------	44	--------	--------	--------	--------
	3	63	--------	--------	3.7	--------	--------	44	--------	--------	--------	--------
	5	61	--------	--------	3.8	--------	--------	45	--------	--------	--------	--------
	7	54	--------	--------	3.9	--------	--------	41	--------	--------	--------	--------

[1] Mature apples were grown in 1948 (first crop year) and 1949 (second crop year); immature apples were grown in 1949.

[2] Mean of 3 replicates expressed in milliliters of N/10 sodium hydroxide required to neutralize 100 grams of apple.

[3] Mean of 3 replicates.

[4] Mean of 3 replicates expressed as percentage of total solids.

TABLE 6.—RAW APPLES: *Pectin and moisture content before and after storage of apples, by crop year* [1]

Variety of apple and storage temperature	Storage time	Total pectin [2]			Pectic acid [2]			Moisture [3]		
		Mature apples		Immature apples	Mature apples		Immature apples	Mature apples		Immature apples
		First crop year	Second crop year		First crop year	Second crop year		First crop year	Second crop year	
Delicious:	*Months*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
32° F.	0	5.06	4.72	4.22	1.36	0.42	0.36	80	82	83
	3	4.80	4.56	4.84	1.06	.54	.35	84	83	83
	5	4.38	4.58	4.85	.88	.66	.62	84	82	83
	7	4.86	4.99	4.80	1.30	.72	.35	84	83	83
40° F.	0	5.06	4.72	4.22	1.36	.42	.36	80	82	83
	3	4.32	4.66	4.58	.90	.59	.33	84	83	83
	5	5.04	4.84	4.84	1.16	1.07	.68	84	84	83
	7	4.68	4.83	4.34	1.30	.60	.58	85	83	83
Golden Delicious:										
32° F.	0	3.97	3.86	3.98	.56	.33	.32	84	83	83
	3	4.24	4.07	4.55	.79	.39	.55	84	82	83
	5	3.44	4.25	4.53	.97	.37	.65	85	82	83
	7	3.76	4.03	4.62	.88	1.26	.55	84	83	83
40° F.	0	3.97	3.86	3.98	.56	.33	.32	84	83	83
	3	4.44	4.47	4.75	1.04	.44	.80	84	82	83
	5	4.21	4.76	4.50	.86	.49	.64	84	84	85
	7	4.12	4.47	4.90	1.19	.96	.48	85	83	85
Jonathan:										
32° F.	0	4.65	4.09	----	1.09	.54	----	84	86	----
	3	4.75	4.19	----	1.24	.03	----	84	85	----
	5	4.37	4.88	----	1.54	.67	----	85	84	----
	7	4.72	5.19	----	1.74	1.82	----	85	86	----

40° F.	0	4.65	4.09	----	1.09	.54	----	84	86	----
	3	5.05	4.68	----	1.52	1.68	----	85	85	----
	5	4.86	5.60	----	1.78	1.73	----	85	86	----
	7	5.02	5.00	----	1.73	1.45	----	84	86	----
Rome Beauty:										
32° F.	0	4.29	4.65	4.85	1.06	.34	.15	84	83	84
	3	4.78	4.73	5.13	.98	.80	.47	85	82	84
	5	5.00	5.50	5.71	1.14	1.41	.92	85	84	85
	7	4.93	4.42	4.97	1.26	1.26	1.41	85	84	85
40° F.	0	4.29	4.65	4.85	1.06	.34	.15	84	83	84
	3	4.96	5.00	5.01	1.09	1.25	.53	85	84	85
	5	5.02	4.79	5.46	1.20	1.51	.96	85	83	84
	7	4.82	4.51	4.97	1.64	1.07	.34	86	83	84
Stayman:										
32° F.	0	4.60	4.40	4.95	1.20	1.25	.34	82	84	83
	3	4.92	3.61	4.17	1.48	1.08	1.40	82	84	83
	5	3.69	4.87	4.26	1.27	1.52	.59	85	83	82
	7	4.57	4.49	4.50	1.30	1.06	1.16	83	83	83
40° F.	0	4.60	4.40	4.95	1.20	1.25	.34	82	84	83
	3	4.27	4.58	4.01	1.14	1.29	1.31	82	84	83
	5	4.04	4.91	4.16	1.16	1.72	1.27	82	85	83
	7	4.10	4.30	4.61	1.24	1.57	1.65	82	84	83
Winesap:										
32° F.	0	4.10	----	----	1.35	----	----	81	----	----
	3	4.66	----	----	1.58	----	----	81	----	----
	5	4.32	----	----	1.36	----	----	82	----	----
	7	4.18	----	----	1.37	----	----	80	----	----
40° F.	0	4.10	----	----	1.35	----	----	81	----	----
	3	4.69	----	----	1.56	----	----	83	----	----
	5	4.48	----	----	1.36	----	----	82	----	----
	7	3.98	----	----	1.26	----	----	81	----	----

[1] Mature apples were grown in 1948 (first crop year) and 1949 (second crop year); immature apples were grown in 1949.

[2] Mean of 3 replicates expressed as percentage of total solids.

[3] Mean of 3 replicates expressed as percentage of total weight.

TABLE 7.—RAW APPLES: *Mean squares in analysis of variance for certain chemical characteristics* [1]

Source of variation	Degrees of freedom	Total acidity [2]	Reducing sugar	Total sugar	Total pectin	Pectic acid	Moisture
FIRST CROP YEAR							
Mature:							
Variety	5	5, 802. 62**	544. 44**	-------	1. 62**	0. 75**	31. 58**
Storage time	3	1, 204. 06**	52. 46	-------	. 30	. 24	9. 66*
Storage temperature	1	117. 56	1. 12	-------	. 14	. 04	. 04
SECOND CROP YEAR							
Mature:							
Variety	4	10, 254. 27**	308. 22**	120. 17**	. 92	1. 65**	16. 33**
Storage time	3	1, 828. 18**	312. 77**	27. 46	1. 17*	1. 56*	. 43
Storage temperature	1	186. 05	54. 35*	36. 37*	. 46	. 73	3. 55
Immature:							
Variety	3	9, 393. 79**	301. 11**	79. 72**	1. 57	. 91	7. 19**
Storage time	3	2, 161. 17**	231. 35**	208. 24**	. 24	1. 01*	. 30
Storage temperature	1	169. 00	63. 32*	3. 70	. 04	. 04	2. 61

[1] *=Significant at the 5-percent level, **=significant at the 1-percent level.
[2] The statistical analysis on total acidity for the first year is based on 3 storage periods (unstored samples excluded).

TABLE 8.—*Coefficients of correlation among various chemical constituents of raw apples* [1]

Correlation factors	pH	Reducing sugars	Total sugars [2]	Total pectin	Pectic acid
Total acidity	−0. 85**	−0. 62**	−0. 17	−0. 13	+0. 30*
pH	----------	+. 70**	−. 02	+. 03	−. 19
Reducing sugars	----------	----------	+. 39*	+. 20	−. 08
Total sugars [2]	----------	----------	-------	−. 45**	−. 26
Total pectin	----------	----------	-------	-------	+. 48**

[1] Mature apples, two crop years combined; *=significant at the 5-percent level, **=significant at the 1-percent level.
[2] Data for second crop year only.

months. Immature Golden Delicious apples had values of 66 before and 30 after storage and Rome Beauty had values of 53 and 15, respectively. All four varieties decreased in acidity with increases in storage time to 5 months but showed little change between the 5- and 7-month storage periods.

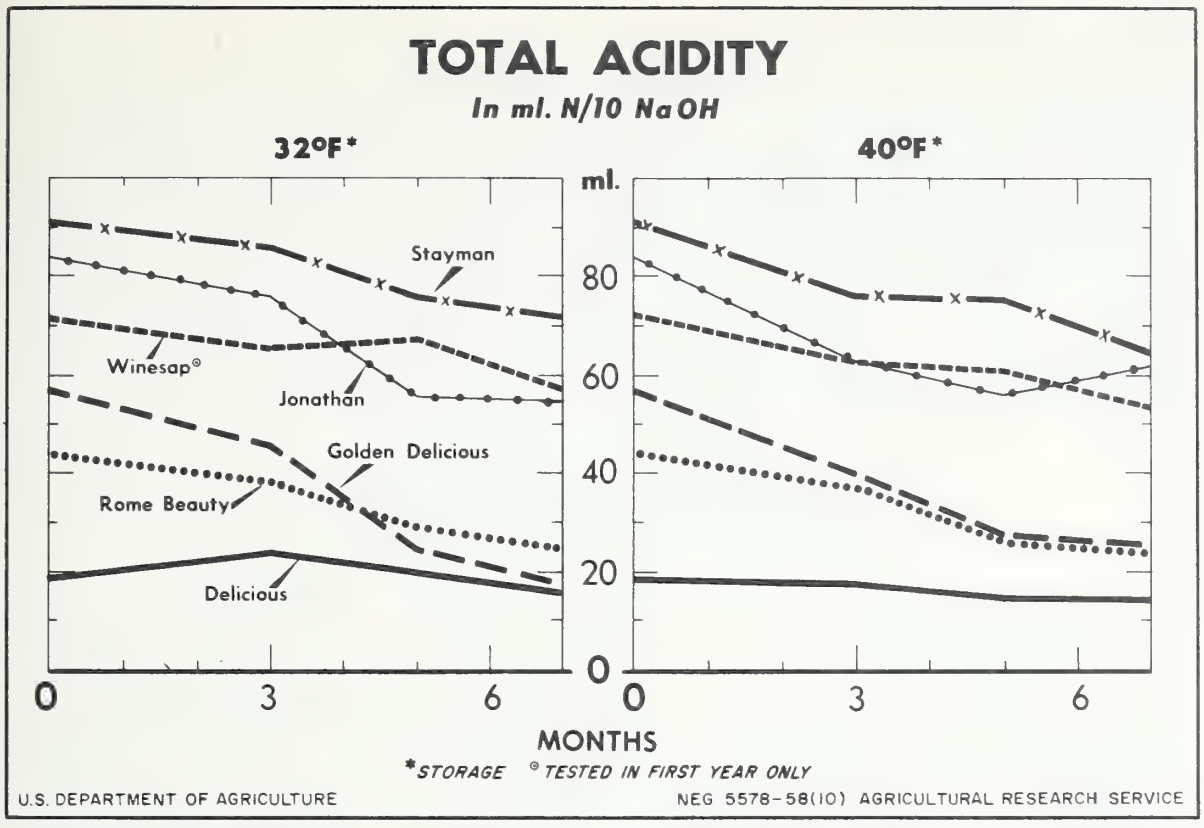


FIGURE 3.—Total acidity of six varieties of mature apples before and after storage at 32° and 40° F., mean values for 2 crop years combined.

pH

Among the mature apples, freshly harvested Stayman apples were the most acid with a pH of 3.3 and Delicious apples were the least acid with a pH of 4.1. These two varieties also were highest and lowest, respectively, in total acidity. The other varieties did not differ greatly in pH, although in total acidity they varied considerably. For example, Rome Beauty and Jonathan had about the same pH, 3.5 and 3.4, although Jonathan had a much higher total acidity than Rome Beauty.

Immature apples when freshly harvested had approximately the same pH values as the corresponding varieties of mature apples and increased in pH during storage to about the same extent as mature apples. It was shown previously that changes in total acidity of immature apples in this study were similar to those in mature apples.

After storage for 7 months at 32° or 40° F., pH values increased in all varieties, but increased less in those with high total acidity. Delicious, Golden Delicious, and Rome Beauty varieties in the group low in total acidity, after storage had the highest pH values and were the only mature varieties with values above pH 4.0. The changes in pH were similar for apples stored at either temperature. Wright and Whiteman (*54*) reported comparable increases in pH from 3.86 to 4.17 in Delicious apples during 7 months of storage, and from 3.46 to 3.55 in Stayman apples during 6 months of storage.

The coefficient of correlation between pH and total acidity of mature apples in this experiment was −0.85. This correlation is highly significant and indicates that 72 percent of the variation in pH is associated with the total acidity of the apples. Barnes (*3*), in a study on 33 varieties of Minnesota apples, reported a coefficient of correlation of −0.93 between pH and titratable acidity.

Reducing Sugar

As shown in figure 4, reducing sugar in the six varieties of mature apples ranged from approximately 34 to 50 percent of the total solids before storage and from 41 to 58 percent after 7 months of storage. Delicious apples were highest in reducing sugar at all times. Stayman apples were lowest in reducing sugar before storage and after 3 months, whereas after 5 and 7 months Rome Beauty and Winesap apples were nearly like Stayman in reducing-sugar content (range of 43 to 49 percent). Immature apples had 34 to 55 percent reducing sugar with the same varieties outstandingly low or high.

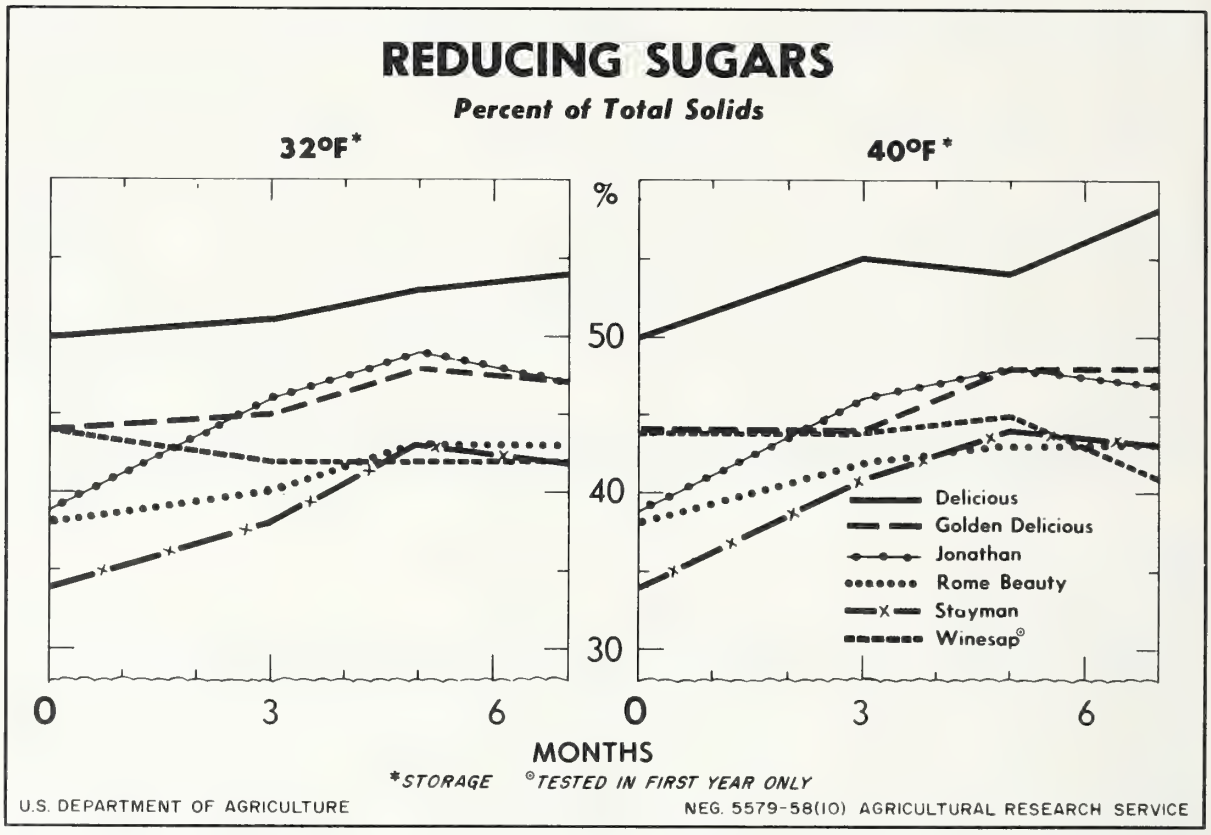


FIGURE 4.—Reducing-sugar content of six varieties of mature apples before and after storage at 32° and 40° F., mean values for 2 crop years combined.

In nearly all tests, the six varieties of mature apples showed increases in reducing sugar with each increment of storage time. Snyder (*41*) reported that invert sugar results from the conversion of starch and sucrose in apples and thus apples become sweeter during storage. Vecher and Bukin (*49*), who are in agreement with his findings, found that other compounds such as pectins and hemicelluloses were also responsible for the increase in invert sugar.

Although all varieties appeared to increase in reducing sugar more rapidly at 40° F. than at the lower temperature, differences related to storage temperature were significant only in the second year for both mature and immature apples.

The coefficient of correlation between values for reducing sugar and total acidity was −0.62 and between reducing sugar and pH, +0.70. Both were highly significant; in other words, 38 percent of the variation in total acidity and 49 percent of the variation in pH, respectively, were associated with the reducing-sugar content of apples in this study.

Total Sugar

For the varieties of mature apples in this study, total sugar content ranged from approximately 54 to 62 percent of the total solids before storage (fig. 5); Rome Beauty was lowest in total sugar; and the other varieties in order of increasing amounts were Stayman, Delicious, Jonathan, and Golden Delicious. Total sugar content in immature apples before storage ranged from approximately 50 to 55 percent in about the same order as the mature varieties.

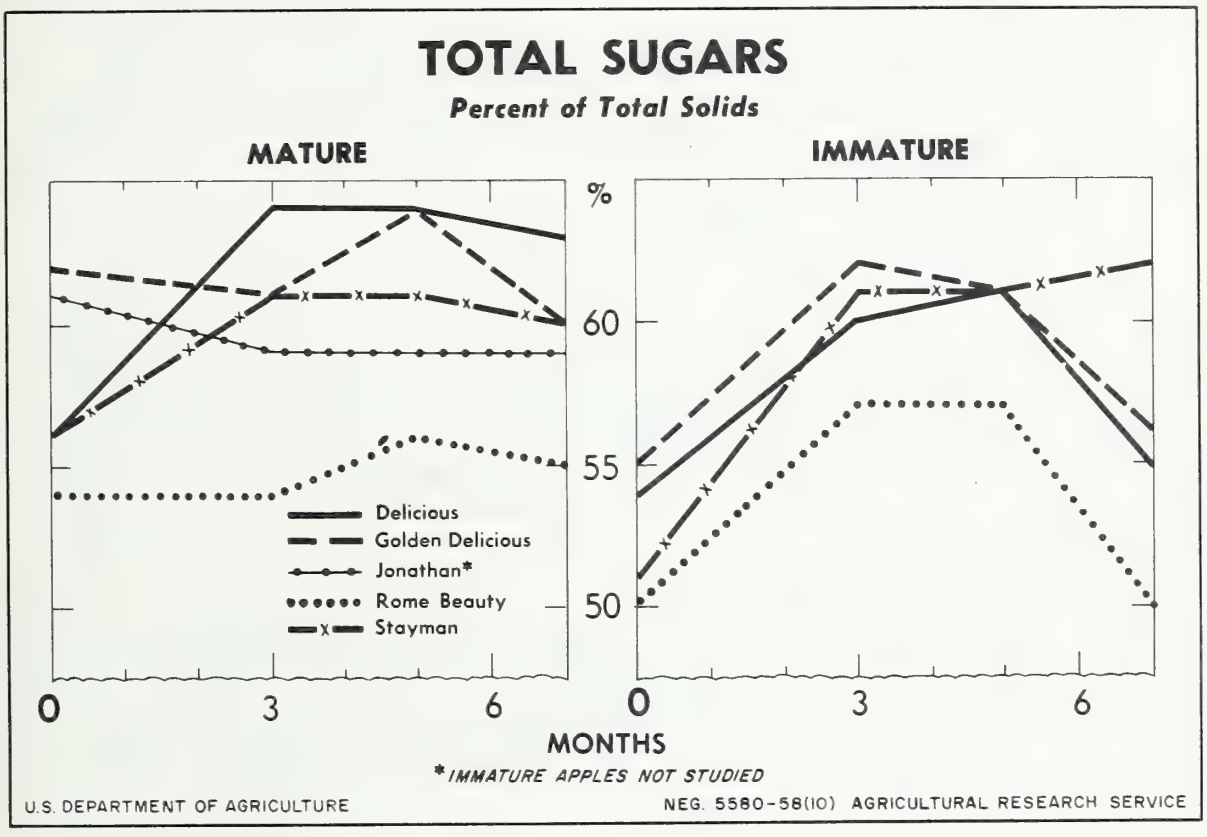


FIGURE 5.—Total sugar content of mature and immature apples, before and after storage at 40° F., for 1 crop year.

Although the total sugar content of mature apples, in general, was not significantly affected by storage time, the differences in values indicated increases in some varieties in the first 3 months of storage followed by slight decreases with longer storage. Immature apples of all varieties increased in total sugar during the first 3 months of storage and in all but one variety decreased after 5 and 7 months of storage. In a study of carbohydrate metabolism of stored McIntosh apples, Krotkov and Helson (*19*) found that the total sugar increased from August until October or November when respiration reached its peak, then decreased corresponding to the decline in respiration. Plagge, Maney, and Gerhardt (*35*), in a study of physical and chemical changes in Grimes apples, reported increases in sugar during storage.

Mature apples stored at 32° F. showed approximately the same trend in total sugar content as those at 40°, with a few exceptions, which made a significant difference in results. After storage of 7 months, Delicious and Stayman apples showed a greater increase in total sugar at 40°, whereas Rome Beauty apples showed a considerable decrease at 32°.

The correlation coefficient between total sugar and reducing sugar was +0.39 representing data from the second crop only. Although

significant at the 5-percent level, it was a low correlation. Coefficients of correlation between total sugar and total acidity and total sugar and pH were too small to be of any consequence.

Total Pectin

Total pectin content of freshly harvested mature apples ranged from 3.92 percent for the Golden Delicious variety to 4.89 percent for the Delicious variety. For the other four varieties it ranged from 4.10 to 4.50 percent. Storage at either 32° or 40° F. had little or no effect on the total pectin content of mature apples. Although the differences in total pectin content were statistically significant for the varieties of apples from the first crop and for the effect of storage time in the second crop year, these differences were extremely small and did not show any consistent trend in both years.

Immature apples contained from 3.98 to 4.95 percent total pectin before storage and there were no significant differences among the four varieties stored at 32° or at 40° F. for various lengths of time.

Correlation coefficients for total pectin content and total acidity, pH, or reducing sugar were not significant. Although the correlation coefficient of −0.45 between total pectin and total sugar was statistically significant, it was too low to be of practical importance.

Pectic Acid

Since the pectic acid content of apples obtained in the two consecutive crop years differed, results are shown graphically for comparison in figure 6. The pectic acid content of freshly harvested apples was lower in the second crop year (range of 0.33 to 1.25 percent) than in the first (range of 0.56 to 1.36 percent). Differences in the

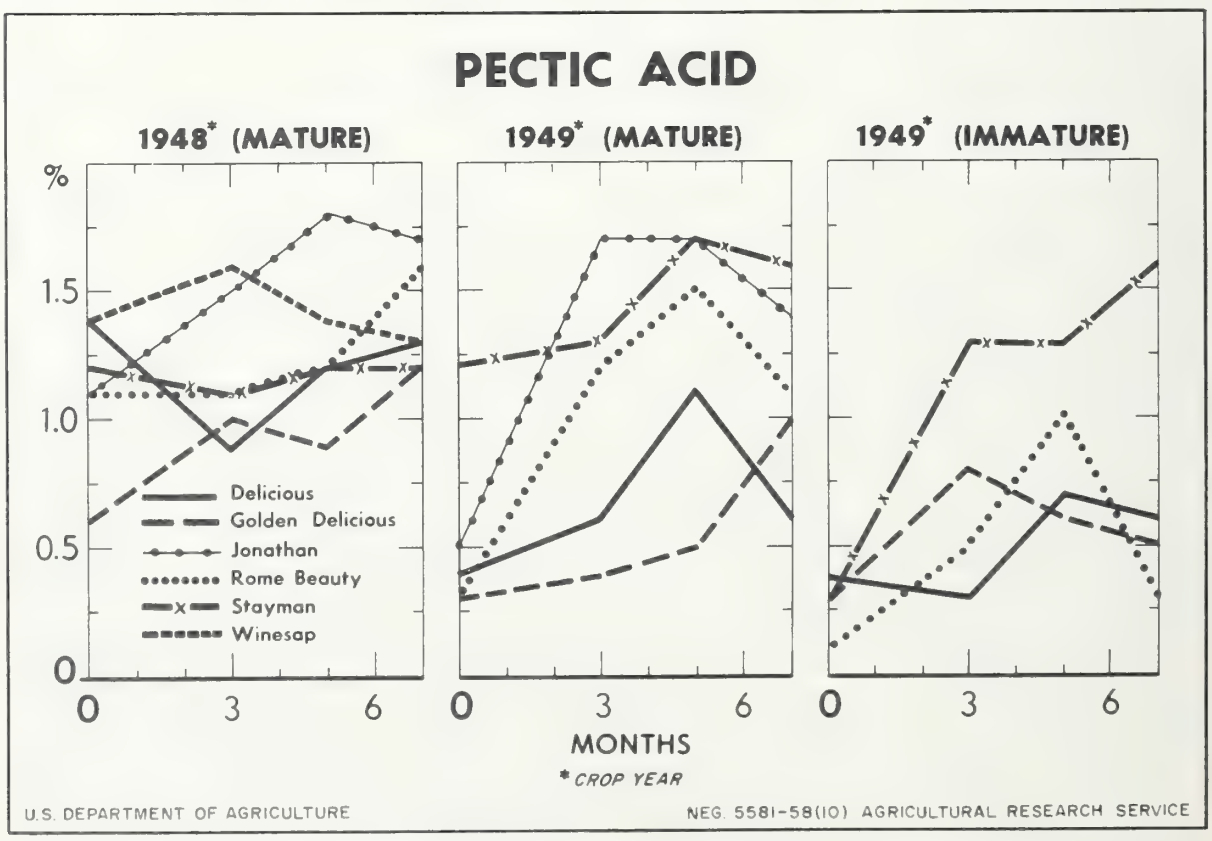


FIGURE 6.—Pectic acid content of mature and immature apples before and after storage at 40° F.

pectic acid content related to storage time of apples were significant in the second year only. Apples showed increases during storage for 7 months, ranging from a low of 0.18 percent for the Delicious variety to a high of 0.91 for the Jonathan. This difference in behavior during storage may have been dependent upon the low initial pectic acid content of the apples in the second year. After storage for 7 months the pectic acid content was very similar in the two crop years.

Immature apples did not differ significantly among varieties in pectic acid content. Values for all varieties were low as were those for the mature apples of the second crop year. The pectic acid content of immature apples increased significantly during storage.

Changes in pectic acid content of apples were similar for the two storage temperatures, 32° and 40° F. The correlations between pectic acid and other compositional factors such as total acidity and total pectin, though significant, were not high. Correlations of pectic acid with pH, reducing sugar, and total sugar were not significant.

Moisture

Varieties of apples differed significantly in moisture content, although the differences were not great. Before storage, the six varieties of mature apples contained from 81 to 85 percent moisture and the four varieties of immature apples ranged from 83 to 84 percent moisture. Throughout storage of the apples the moisture content remained fairly constant.

Palatability characteristics

Appearance and Texture Characteristics of Raw Apples, Applesauce, and Baked Apples

Data on appearance and texture characteristics of raw apples, applesauce, and baked apples are presented in tables 9 to 12. These tables give mean panel scores by crop year and maturity for unstored and stored apples of the different varieties when raw, made into sauce, and baked.

Statistical analyses of the palatability values for raw apples, applesauce, and baked apples are presented in tables 13, 14, and 15, respectively. Coefficients of correlation between raw and cooked apples are shown in table 16.

Skin color of raw apples.—Scores for the skin color of the six varieties of apples indicated that Delicious and Rome Beauty rated higher than the others (fig. 7). The lower scores for Golden Delicious, Jonathan, Stayman, and Winesap indicated some lack of brightness.

During storage all varieties showed some loss of skin color. Delicious and Rome Beauty apples scored above 4.0 at nearly all storage periods. The remaining four varieties scored from approximately 4.5 to 4.0 before storage to approximately 3.5 to 2.0 after 7 months.

Storage temperature of 40° or 32° F. seemed to make little difference in the skin color of Delicious and Rome Beauty apples. In the first year the other four varieties had significantly brighter skin when stored at 32° at nearly all storage periods; the second year, scores were not significantly different for variations in storage temperature.

Flesh color of raw apples and color of applesauce.—Data for flesh color of raw mature apples for both crop years combined indicated

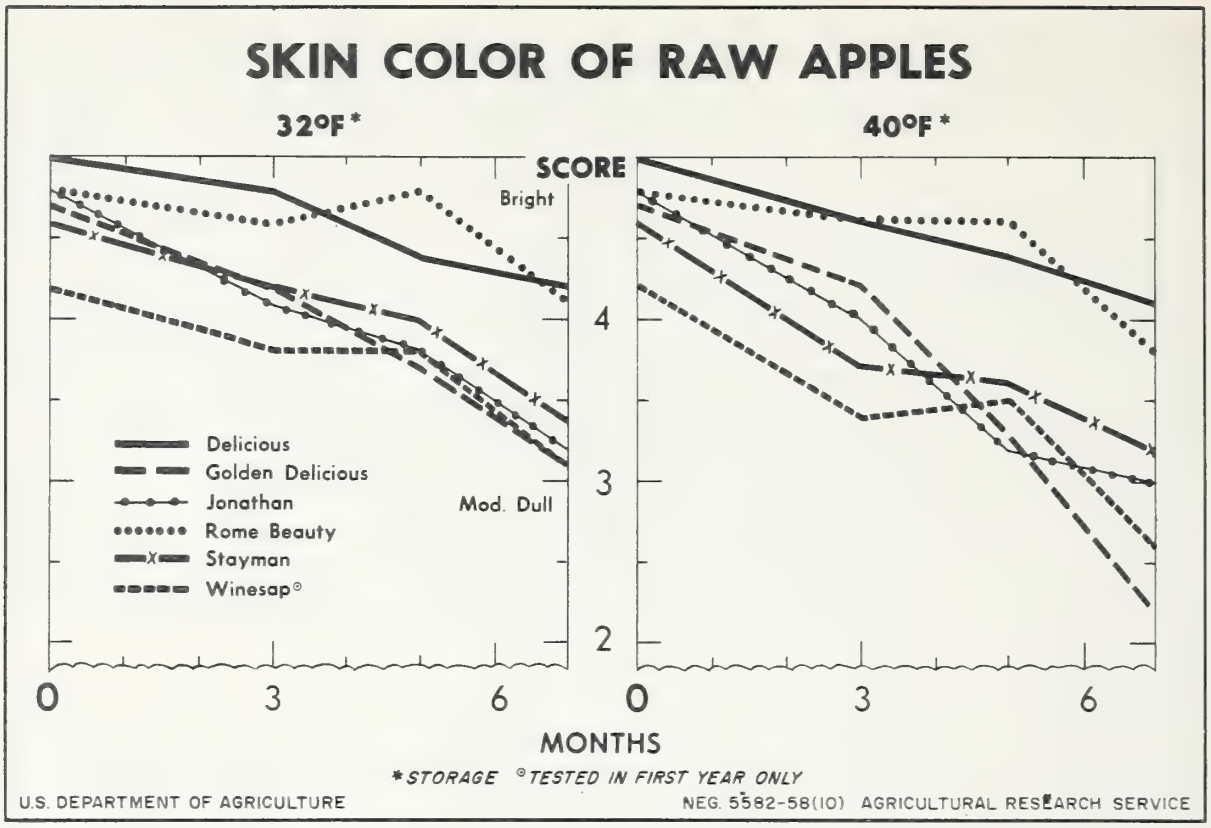


FIGURE 7.—Skin color of raw mature apples before and after storage at 32° and 40° F., mean scores for 2 crop years combined.

no significant differences among varieties. The effect of storage time, however, was highly significant; raw apples of all varieties deteriorated in flesh color to slightly or moderately dark after 7 months in storage (fig. 8). Differences in flesh color of apples stored at 32° and 40° F. were not significant in either crop year.

Flesh color of freshly harvested mature apples of the first year's crop scored from 5.0 to 4.3, with Delicious highest and Winesap lowest. The comparatively low scores for Winesap indicate the poor quality of that variety that year. In the second year the varieties did not differ significantly in flesh color. Among the immature apples, varietal differences were also nonsignificant; Golden Delicious scored 4.9 and the other varieties scored from 4.8 to 4.5.

Sauces made from unstored mature apples of most of the varieties were characteristically bright in color. In 3 out of 4 varieties, sauces made from immature apples were slightly darker than those from mature apples. Golden Delicious apples made sauces that scored approximately the same regardless of maturity.

Increasing the time of storage of mature apples caused most of the applesauces to be darker in color. Sauces made from Jonathan and Stayman varieties, however, were approximately the same in color, as indicated by scores of 4.5 or above at all storage periods. The color of sauces made from immature apples was not significantly influenced by storage time of apples.

Differences in scores for flesh color of apples and color of applesauce related to storage temperature were not great enough for significance.

The coefficient of correlation between scores for flesh color of raw apples and color of applesauce in the first year shows a highly significant relationship; a coefficient of +0.52 indicates that only 27 percent of the variation in scores for color of applesauce could be attributed to scores for flesh color of raw apples.

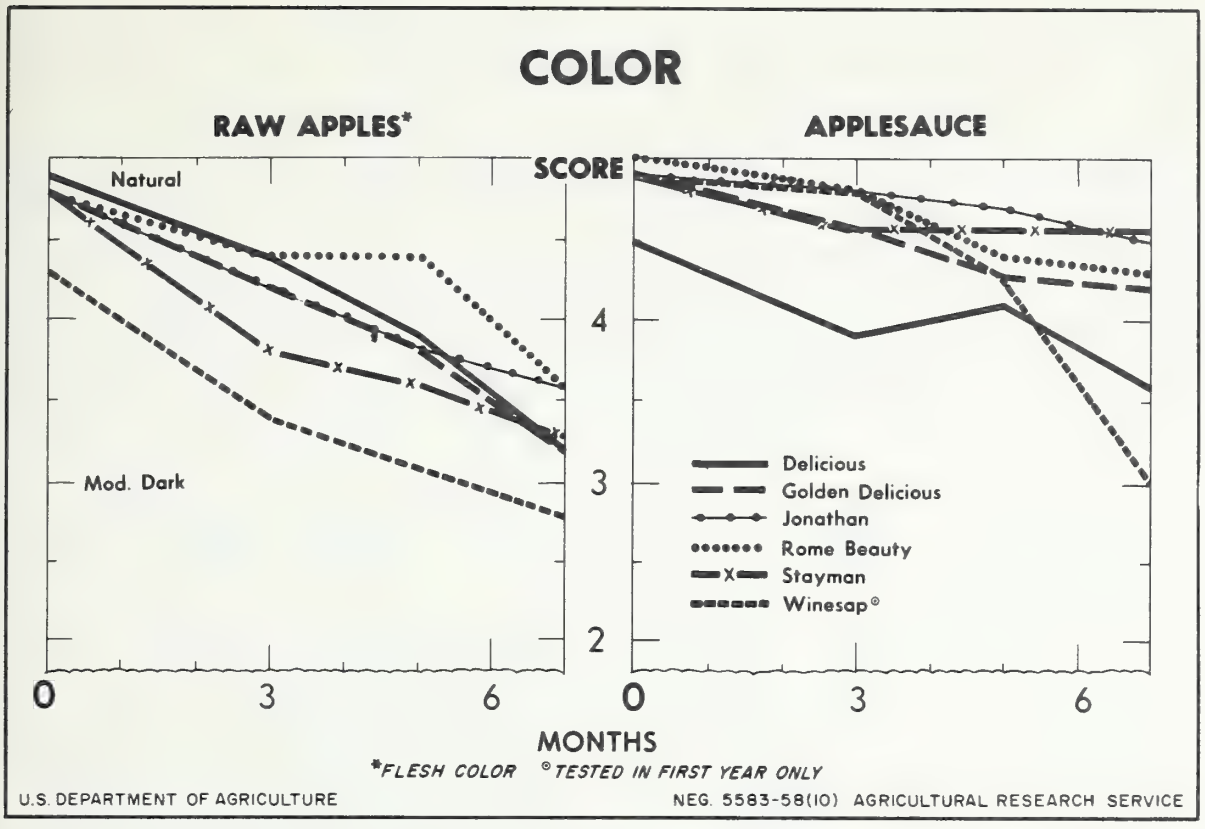


FIGURE 8.—Flesh color of raw apples and color of applesauce before and after storage of mature apples at 40° F., mean scores for 2 crop years combined.

Translucency of applesauce and baked apples.—Scores for sauces made from unstored mature apples ranged from 4.2 to 4.9 for translucency. Sauces made from Stayman apples and those from some samples of Delicious scored lowest; they were described as moderately translucent. Sauces made from immature apples were often less translucent than those from mature fruit. Of the immature apples, Golden Delicious made sauces described as moderately translucent, whereas sauces from the other three varieties received somewhat lower scores, described as slightly translucent.

Sauces made from stored mature apples of the first year's crop showed very little change in translucency until the end of the 7-month storage period; those made from the second year's crop decreased in translucency with shorter storage times. When immature apples were used, sauces from two varieties—Rome Beauty and Stayman—were slightly more translucent after the apples were stored for 3 months than before storage. Sauces made from the other two varieties of immature apples had approximately equal scores whether the apples were unstored or stored for 3 months.

The temperature at which the apples were stored did not significantly influence scores for translucency of applesauce.

Differences in translucency of baked apples, both mature and immature, were significant for variety in the second year only. When unstored apples were baked, Jonathan and Golden Delicious were most translucent. Baked Winesap apples were least translucent and were described as slightly cloudy.

In general, baked apples became less translucent with each increment in storage time of the raw apples. Exceptions were some samples of Rome Beauty, Stayman, and Winesap apples which appeared to give a slightly more translucent baked product after storage than before.

TABLE 9.—RAW APPLES: *Color and texture characteristics before and after storage of apples, by crop year* [1]

Variety of apple and storage temperature	Storage time	Mean panel scores [2] for raw apples											
		Color of skin			Texture of skin			Color of flesh			Texture of flesh		
		Mature apples		Immature apples	Mature apples		Immature apples	Mature apples		Immature apples	Mature apples		Immature apples
		First crop year	Second crop year		First crop year	Second crop year		First crop year	Second crop year		First crop year	Second crop year	
Delicious:	*Months*												
32° F	0	5.0	4.9	4.5	3.9	3.8	3.6	5.0	4.8	4.5	4.8	4.9	5.1
	3	4.6	4.9	4.6	3.9	3.9	3.8	4.3	4.3	4.4	4.5	4.9	5.3
	5	4.4	4.4	4.3	3.6	3.0	3.5	3.7	3.7	3.9	4.7	5.0	4.7
	7	4.0	4.3	4.1	3.6	3.1	3.4	3.7	3.3	3.3	4.0	4.2	4.1
40° F	0	5.0	4.9	4.5	3.9	3.8	3.6	5.0	4.8	4.5	4.8	4.9	5.1
	3	4.6	4.7	4.6	3.5	3.5	3.4	4.5	4.4	4.4	3.7	2.7	2.7
	5	4.3	4.4	4.4	3.3	2.8	3.2	4.0	3.8	3.9	3.3	2.5	2.8
	7	4.1	4.1	3.9	3.4	2.9	2.9	3.3	3.1	3.5	3.3	2.0	1.8
Golden Delicious:													
32° F	0	4.9	4.5	4.6	4.4	4.1	4.0	4.9	4.8	4.9	5.0	3.9	5.4
	3	4.7	3.6	4.0	4.4	3.5	3.9	4.3	4.1	4.7	4.2	3.4	4.3
	5	3.9	3.5	3.7	4.1	3.7	3.6	4.6	3.7	4.2	4.2	3.3	3.7
	7	3.6	2.6	2.9	3.7	3.1	2.9	3.8	3.1	3.3	3.6	2.2	2.7
40° F	0	4.9	4.5	4.6	4.4	4.1	4.0	4.9	4.8	4.9	5.0	3.9	5.4
	3	4.5	3.8	4.1	4.4	3.5	3.9	4.4	4.1	4.5	4.3	3.4	3.5
	5	3.5	3.1	3.4	3.5	3.9	3.7	4.2	3.4	4.1	4.0	2.7	3.1
	7	2.2	2.1	2.5	3.5	3.4	3.1	3.5	2.8	3.3	2.8	1.5	2.5

Jonathan:														
32° F.	0	4.8	4.9	-------	4.2	3.9	-------	4.9	4.9	-------	4.6	4.1	-------	
	3	4.4	3.8	-------	3.3	3.4	-------	4.4	4.3	-------	4.2	3.9	-------	
	5	4.2	3.3	-------	3.6	3.2	-------	3.6	3.9	-------	4.3	3.3	-------	
	7	3.4	2.9	-------	3.1	2.5	-------	3.6	3.4	-------	3.3	3.1	-------	
40° F.	0	4.8	4.9	-------	4.2	3.9	-------	4.9	4.9	-------	4.6	4.1	-------	
	3	4.2	3.7	-------	3.8	3.5	-------	4.1	4.2	-------	4.5	3.7	-------	
	5	3.4	3.0	-------	3.4	3.3	-------	4.1	3.6	-------	3.8	3.3	-------	
	7	3.0	3.1	-------	3.2	2.8	-------	3.5	3.7	-------	3.0	2.7	-------	
Rome Beauty:														
32° F.	0	4.5	5.0	4.8	4.0	3.7	3.7	4.9	4.7	4.8	5.1	4.7	5.7	
	3	4.7	4.6	4.7	3.5	3.7	4.3	4.4	4.5	4.6	3.7	3.2	3.9	
	5	5.0	4.5	4.3	3.3	3.1	3.2	4.6	3.9	4.1	3.5	3.1	3.4	
	7	4.1	4.1	3.9	3.5	3.1	2.9	3.8	3.9	3.5	2.6	2.4	2.7	
40° F.	0	4.5	5.0	4.8	4.0	3.7	3.7	4.9	4.7	4.8	5.1	4.7	5.7	
	3	4.5	4.7	4.6	3.6	3.6	4.0	4.3	4.5	4.3	3.3	2.9	3.5	
	5	4.7	4.5	3.9	3.2	3.3	3.1	4.8	4.0	3.6	3.3	2.7	2.9	
	7	3.9	3.7	2.8	3.2	3.3	2.7	3.7	3.5	3.6	3.0	2.4	2.4	
Stayman:														
32° F.	0	4.6	4.7	4.3	3.6	3.4	3.7	4.7	4.9	4.5	5.4	5.5	5.7	
	3	4.1	4.4	3.9	3.6	3.2	3.1	4.4	4.4	4.2	5.2	4.4	3.5	
	5	3.8	4.1	3.8	3.2	3.3	3.3	3.9	3.9	3.8	4.3	4.2	3.9	
	7	3.4	3.5	3.2	3.1	2.9	2.5	3.3	3.7	3.3	3.8	3.3	3.4	
40° F.	0	4.6	4.7	4.3	3.6	3.4	3.7	4.7	4.9	4.5	5.4	5.5	5.7	
	3	3.3	4.1	4.0	3.4	3.2	3.3	3.5	4.2	4.1	3.4	3.4	3.7	
	5	3.7	3.6	3.2	3.2	2.9	3.3	3.8	3.4	3.5	3.9	2.9	2.9	
	7	2.9	3.5	2.9	2.9	2.8	2.5	2.9	3.5	3.1	2.4	2.5	2.1	
Winesap:														
32° F.	0	4.2	-------	-------	3.1	-------	-------	4.3	-------	-------	3.7	-------	-------	
	3	3.8	-------	-------	3.7	-------	-------	3.3	-------	-------	4.5	-------	-------	
	5	3.8	-------	-------	3.0	-------	-------	3.3	-------	-------	5.1	-------	-------	
	7	3.1	-------	-------	2.9	-------	-------	3.1	-------	-------	3.4	-------	-------	
40° F.	0	4.2	-------	-------	3.1	-------	-------	4.3	-------	-------	3.7	-------	-------	
	3	3.4	-------	-------	3.4	-------	-------	3.4	-------	-------	4.2	-------	-------	
	5	3.5	-------	-------	2.9	-------	-------	3.1	-------	-------	3.7	-------	-------	
	7	2.6	-------	-------	2.6	-------	-------	2.8	-------	-------	2.2	-------	-------	

[1] Mature apples were grown in 1948 (first crop year) and 1949 (second crop year); immature apples were grown in 1949.

[2] Mean of 15 scores (3 replicates by 5 judges). A score of 5 represents highest and 1, lowest, except texture of flesh scored from 9, very firm to 1, very mealy.

TABLE 10.—APPLESAUCE: *Appearance characteristics before and after storage of apples, by crop year* [1]

Variety of apple and storage temperature	Storage time	Mean panel scores [2] for applesauce					
		Color			Translucency		
		Mature apples		Immature apples	Mature apples		Immature apples
		First crop year	Second crop year		First crop year	Second crop year	
Delicious:	*Months*						
32° F.	0	4.8	4.2	3.7	4.7	4.3	3.5
	3	4.0	3.2	2.9	3.9	3.5	3.2
	5	4.1	3.6	2.7	3.7	3.4	2.9
	7	3.2	2.0	2.1	4.0	2.9	2.5
40° F.	0	4.8	4.2	3.7	4.7	4.3	3.5
	3	4.1	3.7	3.2	4.7	4.0	3.7
	5	4.2	4.0	2.9	4.2	4.1	3.5
	7	3.5	3.7	2.9	3.7	3.9	3.5
Golden Delicious:							
32° F.	0	5.0	4.8	4.8	4.9	4.7	4.4
	3	5.0	4.1	4.8	4.9	4.2	4.3
	5	4.8	4.5	4.1	4.9	3.9	4.0
	7	4.6	3.8	4.3	4.5	3.9	4.2
40° F.	0	5.0	4.8	4.8	4.9	4.7	4.4
	3	4.9	4.3	4.7	4.7	4.3	4.5
	5	4.7	3.9	4.0	3.6	3.9	4.1
	7	4.8	3.7	3.4	4.5	3.9	3.7
Jonathan:							
32° F.	0	4.9	4.9	-------	4.9	4.9	-------
	3	4.5	4.7	-------	4.3	4.5	-------
	5	4.9	4.9	-------	4.8	4.3	-------
	7	4.6	4.9	-------	4.3	4.3	-------
40° F.	0	4.9	4.9	-------	4.9	4.9	-------
	3	4.8	4.8	-------	4.6	4.5	-------
	5	4.6	4.8	-------	4.6	4.5	-------
	7	4.5	4.5	-------	4.1	4.3	-------
Rome Beauty:							
32° F.	0	5.0	4.9	3.5	4.7	4.7	3.7
	3	4.9	4.6	4.9	4.6	3.7	4.2
	5	4.7	4.8	4.6	4.7	4.3	3.9
	7	4.6	3.5	4.1	3.9	3.5	3.7
40° F.	0	5.0	4.9	3.5	4.7	4.7	3.7
	3	4.7	4.8	4.5	4.5	3.9	3.9
	5	4.8	4.1	3.9	4.4	3.9	3.3
	7	4.9	3.7	2.8	4.1	3.3	2.6
Stayman:							
32° F.	0	5.0	4.8	4.6	4.2	4.3	3.6
	3	5.0	4.8	4.7	4.5	4.3	4.4
	5	4.5	4.8	4.9	4.6	4.1	4.0
	7	4.6	4.7	4.5	4.1	4.5	4.1
40° F.	0	5.0	4.8	4.6	4.2	4.3	3.6
	3	4.9	4.4	4.2	4.5	4.2	4.2
	5	4.8	4.3	4.3	4.4	4.1	3.9
	7	4.5	4.6	3.9	4.3	4.5	3.9

See footnotes at end of table.

TABLE 10.—APPLESAUCE: *Appearance characteristics before and after storage of apples, by crop year* [1]—Continued

Variety of apple and storage temperature	Storage time	Mean panel scores [2] for applesauce					
		Color			Translucency		
		Mature apples		Immature apples	Mature apples		Immature apples
		First crop year	Second crop year		First crop year	Second crop year	
Winesap:	*Months*						
32° F.	0	4.9	-------	-------	4.7	-------	-------
	3	4.4	-------	-------	4.5	-------	-------
	5	4.6	-------	-------	4.3	-------	-------
	7	3.9	-------	-------	4.2	-------	-------
40° F.	0	4.9	-------	-------	4.7	-------	-------
	3	4.8	-------	-------	4.7	-------	-------
	5	4.3	-------	-------	4.3	-------	-------
	7	3.0	-------	-------	3.8	-------	-------

[1] Mature apples were grown in 1948 (first crop year) and 1949 (second crop year); immature apples were grown in 1949.

[2] Mean of 15 scores (3 replicates by 5 judges). A score of 5 represents highest and 1, lowest.

Differences in translucency of baked apples related to storage temperature of apples were slight. There was some indication that a few samples stored at 40° F. were slightly more translucent when baked than those stored at 32°.

Skin texture of raw and baked apples.—Most varieties of raw mature apples scored between 4.0 (tender) and 3.0 (moderately tough) for skin texture during the storage periods studied (fig. 9). Exceptions were Golden Delicious, the variety with the most tender skin, which scored above 4.0 in early storage, and Winesap and some samples of Stayman apples, which scored below 3.0 in later storage. Varietal differences in scores for skin texture of immature apples were not great enough for significance.

The skin of all the raw apples in this study became less tender with increasing storage time, and after 7 months of storage it was described as moderately tough (scores 3.7 to 2.5).

On many of the raw mature apples the skin was slightly more tender when the apples were stored at 32° F. than at 40°, although scores were significantly different in the first year only. For immature apples, differences between scores for skin texture related to storage temperature, as shown by analysis of variance, were not great enough for significance.

When the six varieties of mature apples were baked before storage, scores for texture of skin ranged from approximately 4.2 (tender) to 3.6 (slightly tough); Jonathan scored highest and Delicious and Winesap, lowest. Differences between scores for Golden Delicious in the two years probably are attributable to the lower quality at harvest in the second year. Of the immature apples, Golden Delicious

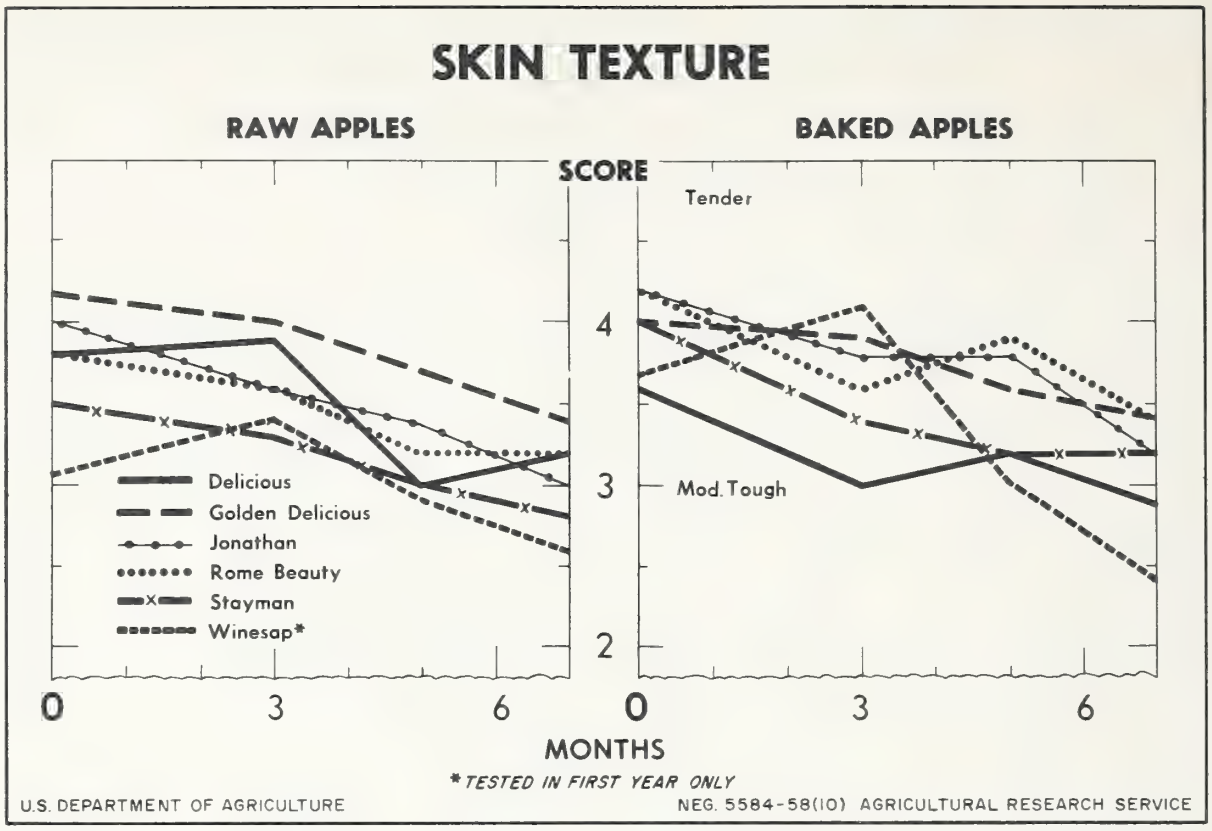


FIGURE 9.—Skin texture of raw and baked apples before and after storage of mature apples at 40° F., mean scores for 2 crop years combined.

had the most tender skin when baked (score 4.2) and Delicious the least tender (score 3.2, slightly to moderately tough).

As expected, tenderness of skin in baked apples decreased with increases in storage time of apples. The skin of all varieties of baked apples was slightly to moderately tough after 7 months of storage. Mature Winesap apples and some samples of both mature and immature Delicious apples baked after storage for 7 months had skins too tough for satisfactory scores.

There was some indication from the scores that for most of the varieties of apples, storage at 32° F. resulted in more tender skins in baked apples than did storage at 40°. However, differences in score were significant in the first year only.

From correlations of the data, a coefficient of +0.65 indicates that 42 percent of the variation in scores for skin texture of these baked apples could be attributed to scores for skin texture of the raw apples.

Flesh texture of raw apples.—At harvest, mature apples of Delicious, Golden Delicious, Jonathan, and Rome Beauty varieties were judged firm and crisp in texture with average scores ranging from 4.4 to 4.9 with 5.0 as optimum firmness (fig. 10). Stayman apples scored above 5.0 for flesh texture because they were more firm than optimum, whereas Winesap apples scored below 5.0. All immature apples were too firm for good eating quality before storage.

Although texture of all apples developed mealiness with increase in storage time, the mature apples were not too mealy to be acceptable after as long as 5 months. Acceptable scores for flesh texture after 7 months were largely dependent on storage temperature.

Storage temperature had a marked effect on the development of mealiness in apples during storage. In general, all scores for flesh

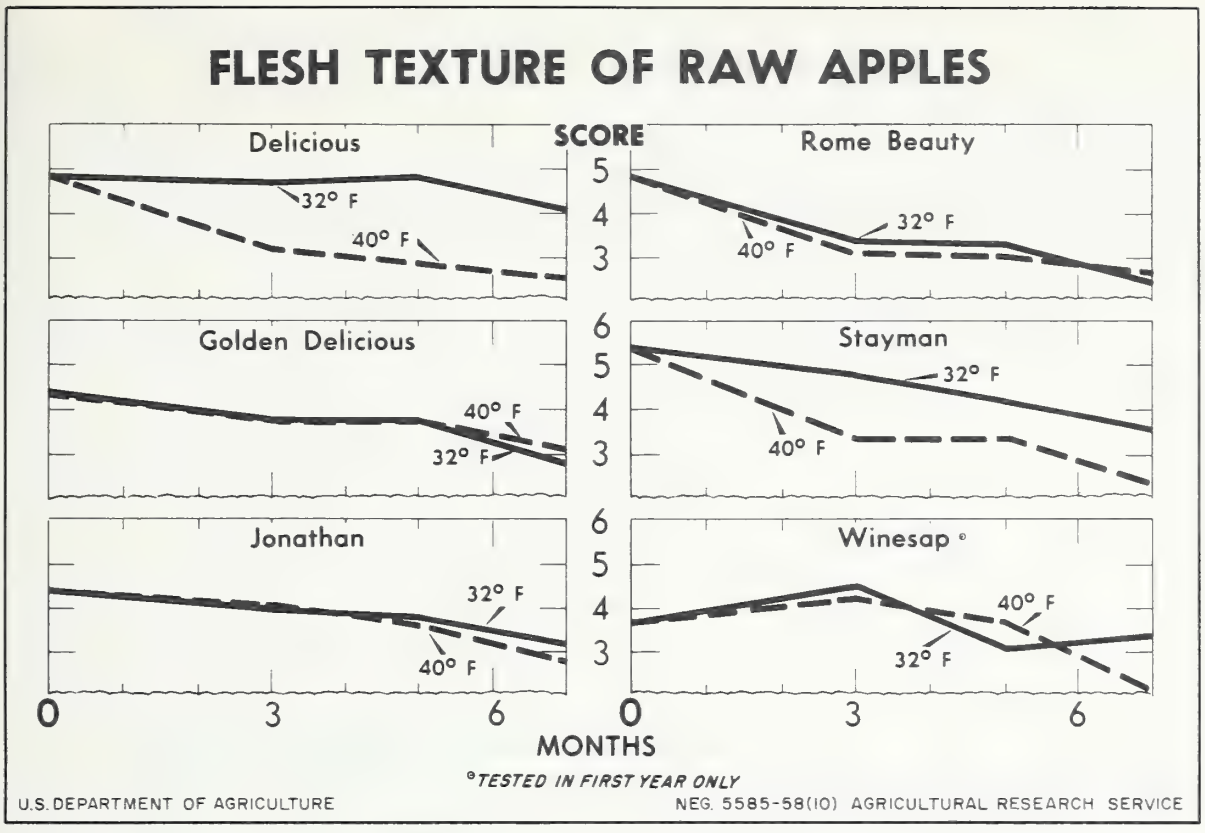


FIGURE 10.—Flesh texture of raw mature apples before and after storage at 32° and 40° F., mean scores for 2 crop years combined.

texture at storage periods of 3, 5, and 7 months were higher when apples were stored at 32° F. rather than at 40°. Delicious apples, stored at 32° for 3 months were nearly as firm as at harvest, whereas Staymans, slightly too firm at harvest, became nearer optimum in texture. These results are in agreement with the report of Magness and associates (*24*), which states that apples of the Stayman variety when stored at 32° became ideal for eating by January. After 3 months' storage at 40°, however, both Delicious and Stayman varieties showed considerable increase in mealiness.

Magness and coworkers (*25*) and Wright, Rose, and Whiteman (*53*) reported from measurements of a pressure tester, that the average softening rate of apples stored at 40° F. was slightly more than double that at 32°. Although objective measurements for flesh texture were not made in this study, the judges scored Golden Delicious, Jonathan, Rome Beauty, and Winesap apples more mealy when stored at 40°. After 7 months of storage at 32°, five of the varieties scored near 3.0 for flesh texture and were acceptable, whereas at 40° only one variety had acceptable flesh texture. These results are in agreement with those of Fisher and Smith (*13*), who found that storage temperature, as well as maturity at harvest, was a factor in the time apples could be satisfactorily stored.

Scores for flesh texture of immature apples stored at 32° and 40° F. show that Delicious apples stored for 7 months at the lower temperature were acceptable, but those stored at 40° were too mealy to be acceptable after 3 months. The other three varieties scored approximately 3.0 or above for 5 months at either storage temperature. Stayman apples had acceptable scores for as long as 7 months when stored at 32°

TABLE 11.—APPLESAUCE: *Texture characteristics and linespread measurements before and after storage of apples, by crop year* [1]

Variety of apple and storage temperature	Storage time	Texture scores [2]			Consistency scores [2]			Linespread measurements [3]		
		Mature apples		Immature apples	Mature apples		Immature apples	Mature apples		Immature apples
		First crop year	Second crop year		First crop year	Second crop year		First crop year	Second crop year	
Delicious:	*Months*									
32° F.	0	4.5	3.5	3.1	5.5	4.7	5.9	4.1	6.9	4.7
	3	4.5	3.1	3.2	5.1	5.4	5.4	6.6	8.4	9.3
	5	4.5	3.3	2.9	5.7	5.8	5.7	5.5	7.9	6.5
	7	5.1	3.1	2.7	4.9	5.3	5.3	9.3	8.4	8.2
40° F.	0	4.5	3.5	3.1	5.5	4.7	5.9	4.1	6.9	4.7
	3	5.3	4.8	4.5	4.8	4.5	3.8	10.0	12.3	12.7
	5	5.2	4.7	4.0	4.8	4.6	5.0	9.8	9.9	10.1
	7	5.2	4.9	4.3	5.9	4.7	5.1	11.3	10.4	9.1
Golden Delicious:										
32° F.	0	5.1	6.2	6.2	5.3	5.1	6.4	5.3	5.5	4.1
	3	5.4	5.5	5.0	4.8	5.4	5.2	9.0	6.3	7.1
	5	4.9	5.4	4.3	5.0	6.3	5.7	8.0	4.4	6.1
	7	4.8	5.3	4.7	5.2	6.7	5.2	8.0	3.7	5.8
40° F.	0	5.1	6.2	6.2	5.3	5.1	6.4	5.3	5.5	4.1
	3	5.1	5.1	5.3	4.9	5.1	5.3	8.5	7.1	6.4
	5	5.5	5.4	4.8	5.3	6.3	5.5	6.1	4.4	6.8
	7	4.9	6.1	4.5	5.1	6.8	5.6	9.3	3.9	6.4
Jonathan:										
32° F.	0	5.1	5.9	-------	4.5	4.4	-------	7.0	7.5	-------
	3	5.3	5.6	-------	5.2	4.7	-------	7.5	10.2	-------
	5	5.8	5.3	-------	5.1	5.0	-------	8.2	9.4	-------
	7	5.2	4.9	-------	5.1	4.3	-------	8.8	10.3	-------

40° F.	0	5.1	5.9	----	4.5	4.4	----	7.0	7.5	----
	3	5.3	4.8	----	5.4	4.5	----	8.8	11.9	----
	5	5.2	4.9	----	5.1	4.9	----	9.2	10.6	----
	7	4.6	5.0	----	5.2	4.9	----	7.6	9.5	----
Rome Beauty:										
32° F.	0	4.8	5.1	4.7	6.1	6.3	6.6	3.3	2.9	3.2
	3	4.7	4.7	5.1	6.1	6.5	5.5	4.8	4.5	5.7
	5	4.4	4.2	4.5	6.1	6.5	6.5	5.3	4.8	5.0
	7	4.2	3.9	3.7	6.1	7.1	6.3	6.6	4.1	5.0
40° F.	0	4.8	5.1	4.7	6.1	6.3	6.6	3.3	2.9	3.2
	3	5.0	4.9	5.0	5.5	6.3	5.6	6.9	5.9	6.4
	5	5.1	4.3	4.1	5.5	6.7	6.5	7.1	5.0	5.3
	7	4.6	4.3	3.1	5.8	6.9	6.9	8.1	4.3	5.1
Stayman:										
32° F.	0	5.7	5.9	6.1	7.0	6.1	7.0	3.1	4.4	2.9
	3	5.9	5.9	5.8	5.1	4.8	4.7	5.7	8.6	7.7
	5	6.2	5.9	5.3	4.9	5.5	4.7	8.1	8.1	7.7
	7	5.9	5.5	5.1	4.8	4.9	4.7	9.8	9.0	9.0
40° F.	0	5.7	5.9	6.1	7.0	6.1	7.0	3.1	4.4	2.9
	3	5.2	5.4	5.3	4.9	5.0	4.2	10.4	9.6	11.5
	5	6.2	5.8	4.7	5.0	4.8	4.6	7.7	11.6	10.9
	7	5.7	5.6	5.1	5.2	4.7	5.0	11.5	13.2	11.9
Winesap:										
32° F.	0	4.5	----	----	5.5	----	----	4.4	----	----
	3	4.8	----	----	6.6	----	----	3.6	----	----
	5	4.4	----	----	6.7	----	----	4.4	----	----
	7	3.8	----	----	6.8	----	----	6.0	----	----
40° F.	0	4.5	----	----	5.5	----	----	4.4	----	----
	3	5.3	----	----	5.9	----	----	4.2	----	----
	5	4.6	----	----	6.2	----	----	5.8	----	----
	7	4.0	----	----	5.9	----	----	7.6	----	----

[1] Mature apples were grown in 1948 (first crop year) and 1949 (second crop year); immature apples were grown in 1949.

[2] Mean of 15 scores (3 replicates by 5 judges). Texture scored from 9, very smooth to 1, very granular. Consistency scored from 9, very thick to 1, very thin.

[3] Linespread expressed in eighths of an inch.

TABLE 12.—BAKED APPLES: *Texture and appearance characteristics before and after storage of apples, by crop year* [1]

Variety of apple and storage temperature	Storage time	Mean panel scores [2] for baked apples											
		Wholeness			Texture of skin			Texture of flesh			Translucency		
		Mature apples		Immature apples	Mature apples		Immature apples	Mature apples		Immature apples	Mature apples		Immature apples
		First crop year	Second crop year		First crop year	Second crop year		First crop year	Second crop year		First crop year	Second crop year	
Delicious:	*Months*												
32° F.	0	4.1	4.0	4.0	3.7	3.5	3.2	4.6	4.8	5.7	3.6	3.4	3.1
	3	4.2	4.0	4.1	3.1	3.1	2.9	5.1	5.9	6.5	3.2	3.3	2.9
	5	4.0	4.0	4.1	3.8	3.1	2.7	4.2	5.3	6.1	3.1	2.6	2.5
	7	3.6	3.9	4.0	3.5	2.7	2.6	3.5	5.1	4.9	3.3	2.3	2.3
40° F.	0	4.1	4.0	4.0	3.7	3.5	3.2	4.6	4.8	5.7	3.6	3.4	3.1
	3	4.3	4.0	4.1	3.1	2.9	2.9	3.7	2.8	3.4	3.3	3.3	3.2
	5	4.2	3.8	3.9	3.4	2.9	2.7	3.6	2.4	3.3	3.2	2.7	2.9
	7	3.5	3.9	3.9	3.1	2.7	2.5	3.1	1.9	2.3	3.1	2.5	2.1
Golden Delicious:													
32° F.	0	3.0	2.9	2.0	4.3	3.6	4.2	4.5	2.8	3.6	3.8	4.2	4.2
	3	2.3	2.3	1.8	4.5	3.7	3.8	3.9	3.1	2.8	4.2	3.7	3.7
	5	2.6	2.9	2.3	4.1	3.4	3.3	3.6	2.8	2.7	3.6	2.9	3.4
	7	3.2	3.0	2.7	3.6	3.1	3.7	3.4	3.2	2.5	3.9	2.7	3.2
40° F.	0	3.0	2.9	2.0	4.3	3.6	4.2	4.5	2.8	3.6	3.8	4.2	4.2
	3	2.1	1.6	1.5	4.2	3.6	3.3	3.6	2.5	2.4	4.1	3.5	3.7
	5	2.5	2.4	2.9	3.7	3.4	3.5	3.6	2.5	2.7	3.6	3.4	3.4
	7	2.6	2.7	2.7	3.7	3.1	3.1	3.0	2.5	2.7	3.5	2.9	3.1

Jonathan:														
32° F.	0	1.9	2.5	-------	4.1	4.3	-------	3.8	3.1	-------	4.1	4.3	-------	
	3	3.6	2.5	-------	4.3	4.1	-------	3.8	3.1	-------	3.8	3.7	-------	
	5	3.7	3.1	-------	3.6	3.9	-------	4.2	2.6	-------	3.6	3.2	-------	
	7	3.2	2.9	-------	3.6	3.3	-------	3.8	2.3	-------	3.2	3.2	-------	
40° F.	0	1.9	2.5	-------	4.1	4.3	-------	3.8	3.1	-------	4.1	4.3	-------	
	3	3.7	2.6	-------	3.8	3.9	-------	4.6	3.1	-------	3.9	3.9	-------	
	5	3.5	2.9	-------	3.7	3.8	-------	3.8	3.0	-------	3.9	3.7	-------	
	7	3.0	2.9	-------	3.3	3.1	-------	3.7	2.9	-------	2.9	3.7	-------	
Rome Beauty:														
32° F.	0	3.0	3.6	3.3	4.2	4.3	3.9	4.2	3.9	4.8	4.0	4.0	3.4	
	3	3.2	4.0	3.9	3.6	4.0	4.3	3.8	3.5	4.3	3.6	2.9	3.3	
	5	3.6	4.0	4.1	4.3	3.5	3.4	4.2	4.2	4.7	4.4	3.1	2.9	
	7	3.6	3.9	3.1	3.2	3.8	3.2	4.0	3.9	4.2	2.6	2.8	2.5	
40° F.	0	3.0	3.6	3.3	4.2	4.3	3.9	4.2	3.9	4.8	4.0	4.0	3.4	
	3	3.3	3.7	3.9	3.5	3.8	3.7	3.8	3.2	4.7	3.7	3.2	2.8	
	5	3.8	3.5	4.0	4.0	3.8	3.4	3.7	3.2	4.3	3.8	3.5	2.8	
	7	3.3	3.7	3.7	3.4	3.4	3.0	3.7	3.8	4.1	3.1	2.5	2.1	
Stayman:														
32° F.	0	1.3	1.4	1.1	4.1	3.9	4.0	2.8	3.3	2.7	3.7	3.9	3.6	
	3	1.3	2.0	1.3	3.8	3.4	3.7	2.5	2.6	1.8	4.0	4.0	3.6	
	5	1.5	2.0	1.1	3.6	3.2	3.3	2.4	2.5	2.1	3.5	3.2	2.8	
	7	1.9	2.7	1.1	3.7	3.2	3.0	2.5	2.4	1.5	3.1	3.3	3.1	
40° F.	0	1.3	1.4	1.1	4.1	3.9	4.0	2.8	3.3	2.7	3.7	3.9	3.6	
	3	1.3	1.6	1.3	3.7	3.0	3.7	2.1	1.8	2.0	3.1	4.2	3.5	
	5	1.4	1.7	1.4	3.2	3.3	3.5	1.8	1.5	1.8	3.8	3.3	2.8	
	7	1.9	2.2	1.5	3.4	3.1	3.3	2.1	1.7	1.6	3.4	3.3	3.2	
Winesap:														
32° F.	0	3.8	-------	-------	3.7	-------	-------	4.9	-------	-------	3.1	-------	-------	
	3	4.0	-------	-------	3.9	-------	-------	3.8	-------	-------	3.9	-------	-------	
	5	3.9	-------	-------	3.6	-------	-------	3.7	-------	-------	3.9	-------	-------	
	7	4.2	-------	-------	2.8	-------	-------	4.7	-------	-------	3.4	-------	-------	
40° F.	0	3.8	-------	-------	3.7	-------	-------	4.9	-------	-------	3.1	-------	-------	
	3	3.8	-------	-------	4.1	-------	-------	4.0	-------	-------	3.6	-------	-------	
	5	3.6	-------	-------	3.0	-------	-------	3.3	-------	-------	3.4	-------	-------	
	7	4.6	-------	-------	2.4	-------	-------	3.9	-------	-------	2.8	-------	-------	

[1] Mature apples were grown in 1948 (first crop year) and 1949 (second crop year); immature apples were grown in 1949.

[2] Mean of 15 scores (3 replicates by 5 judges). A score of 5 represents highest and 1, lowest, except texture of flesh scored from 9, very hard to 1, very soft.

TABLE 13.—RAW APPLES: *Mean squares in the analysis of variance for palatability characteristics and general acceptability* [1]

Source of variation	Degrees of freedom	Color of skin	Texture of skin	Color of flesh	Texture of flesh	Natural flavor	Absence of off-flavor	Sweetness	Tartness	General acceptability
FIRST CROP YEAR										
Mature:										
Variety	5	3. 31**	2. 44**	3. 10**	0. 96	1. 15**	2. 63**	6. 73**	18. 18**	1. 99**
Storage time	3	10. 51**	2. 92**	11. 55**	16. 73**	15. 06**	17. 33**	13. 54**	19. 55**	10. 76**
Storage temperature	1	2. 89**	. 43*	. 26	7. 50**	1. 02*	. 23	2. 89**	2. 68**	1. 60**
Mature, excluding unstored sample:										
Variety	5	3. 54**	1. 50**	2. 88**	1. 14	. 47*	2. 77**	6. 24**	15. 70**	1. 02**
Storage time	2	7. 53**	2. 13**	5. 07**	11. 22**	7. 72**	10. 40**	13. 16**	10. 41**	6. 71**
Storage temperature	1	3. 84**	. 58*	. 35	9. 98**	. 14	. 30	3. 84**	3. 58**	2. 14**
SECOND CROP YEAR										
Mature:										
Variety	4	5. 70**	. 90*	. 42	3. 75	1. 68	1. 19*	18. 98**	34. 56**	1. 44*
Storage time	3	10. 29**	3. 62**	11. 50**	19. 96**	22. 58**	20. 61**	9. 77**	25. 22**	10. 50**
Storage temperature	1	. 43	0	. 26	11. 94	1. 43	1. 82**	3. 83*	5. 04*	2. 35*
Immature:										
Variety	3	2. 98**	. 89	. 57**	. 25	3. 56**	. 07	10. 21**	26. 39**	. 77
Storage time	3	7. 74**	3. 94**	7. 96**	32. 65**	11. 43**	14. 97**	20. 93**	39. 35**	10. 09**
Storage temperature	1	. 95	. 21	. 21	14. 84*	. 05	1. 44*	5. 85*	4. 34*	1. 68**

All apples, temperatures combined:										
Variety	3	16. 79**	4. 06**	. 66	7. 29*	9. 12**	1. 84	52. 52**	115. 75**	1. 69
Storage time	3	28. 98**	11. 59**	34. 43**	101. 88**	62. 17**	63. 56**	62. 19**	133. 08**	50. 69**
Maturity	1	1. 80	. 03	. 14	12. 04	2. 27	1. 32	16. 62	10. 47	. 38
BOTH YEARS										
Mature, temperatures combined:										
Variety	4	13. 23**	4. 76**	1. 21	6. 51*	2. 62	2. 39	51. 74**	111. 96**	. 47
Storage time	3	37. 82**	12. 54**	40. 57**	72. 47**	69. 18**	66. 87**	40. 34**	85. 39**	53. 36**
Crop year	1	1. 36	7. 38**	2. 39	33. 87**	8. 81	7. 34	41. 04**	41. 71*	10. 03

[1] *=Significant at the 5-percent level, **=significant at the 1-percent level.

TABLE 14.—APPLESAUCE: *Mean squares in the analysis of variance for palatability characteristics, linespread, and general acceptability* [1]

Source of variation	Degrees of freedom	Color	Translucency	Texture	Consistency	Natural flavor	Absence of off-flavor	Sweetness	Tartness	General acceptability	Linespread (eighths of an inch)
FIRST CROP YEAR											
Mature, temperatures combined:											
Variety	5	13. 51**	4. 46*	26. 92**	34. 34*	4. 37**	11. 80**	23. 79**	49. 13**	5. 54*	-------
Storage time	3	19. 18**	13. 34**	7. 61	. 70	59. 62**	99. 67**	42. 02**	31. 92**	44. 27**	-------
Cooking time	2	9. 78**	2. 60**	14. 46**	2. 05	2. 76**	. 05	. 31	1. 12	. 72	-------
Mature, excluding unstored sample, temperatures combined:											
Variety	5	15. 69**	4. 99**	23. 19**	37. 17**	4. 97**	10. 25**	23. 80**	52. 73**	6. 65**	-------
Storage time	2	11. 54**	11. 04**	10. 36	. 70	42. 28**	90. 68**	27. 86**	28. 34**	36. 50**	-------
Cooking time	2	10. 85**	3. 14**	10. 34**	1. 08	2. 48**	. 02	. 32	. 75	. 33	-------
Mature, 15-minute cooked:											
Variety	5	2. 41**	. 93*	4. 91**	5. 28*	. 71	1. 87**	3. 69**	8. 81**	. 79	34. 31*
Storage time	3	3. 02**	1. 91**	. 71	. 49	10. 50**	16. 71**	7. 54**	6. 28**	7. 48**	104. 79**
Storage temperature	1	. 03	. 04	. 66*	. 92*	. 00	. 14	. 49	. 03	. 01	37. 34**
SECOND CROP YEAR											
Mature, 15-minute cooked:											
Variety	4	5. 56**	1. 99*	13. 47**	14. 42**	3. 84**	2. 09	10. 30**	25. 52**	5. 39**	140. 41**
Storage time	3	3. 22**	2. 63**	. 89	1. 40	15. 09**	12. 48**	9. 72**	17. 36**	12. 34**	50. 80*
Storage temperature	1	. 01	. 41	3. 47	1. 01	. 13	. 89**	. 32	. 04	. 11	35. 04

Immature:											
Variety	3	10. 52**	3. 74**	18. 58**	5. 35*	5. 46**	2. 42	3. 72**	18. 66**	5. 02**	64. 82*
Storage time	3	2. 57	1. 13*	4. 47	8. 40*	8. 65**	8. 39**	11. 68**	21. 59**	8. 29**	101. 24**
Storage temperature	1	1. 34	. 04	. 47	. 10	. 42	. 85	. 04	. 29	. 28	35. 82
All applesauce, temperatures combined:											
Variety	3	29. 44**	8. 80**	71. 94**	33. 53*	13. 74**	4. 99	20. 77**	81. 07**	15. 74**	----
Storage time	3	11. 15*	4. 57	5. 31	10. 11	41. 81**	38. 69**	43. 10**	77. 65**	37. 03**	----
Maturity	1	6. 99*	7. 94	17. 13*	. 00	2. 49	. 19	3. 55	. 62	1. 76	----
BOTH YEARS											
Mature, 15-minute cooked, temperatures combined:											
Variety	4	14. 14**	5. 12	27. 55**	28. 75**	5. 81*	1. 90**	28. 42**	69. 08**	7. 25	----
Period	3	10. 00**	7. 43**	. 38	2. 02	43. 91**	48. 42**	30. 20**	39. 89**	32. 19**	----
Crop year	1	9. 94**	8. 92*	. 22	1. 71	24. 88	39. 09**	24. 98**	43. 32*	26. 45*	----

[1] *=Significant at the 5-percent level, **=significant at the 1-percent level.

TABLE 15.—BAKED APPLES: *Mean squares in the analysis of variance for palatability characteristics and general acceptability* [1]

Source of variation	Degrees of freedom	Wholeness	Texture of skin	Texture of flesh	Translucency of flesh	Natural flavor	Absence of off-flavor	Sweetness	Tartness	General acceptability
FIRST CROP YEAR										
Mature:										
Variety	5	21. 44**	1. 60*	10. 64**	0. 84	1. 42*	2. 57**	4. 17*	8. 39**	2. 16**
Storage time	3	. 99	3. 30**	3. 56*	2. 27*	9. 85**	19. 05**	6. 45**	5. 12**	6. 03**
Storage temperature	1	. 09	. 86**	2. 13**	. 21	. 91**	2. 55**	. 01	. 62**	1. 31**
Mature, excluding unstored sample:										
Variety	5	16. 36**	1. 15	8. 15**	. 66	. 53	1. 38**	3. 27**	7. 76**	1. 47**
Storage time	2	. 18	2. 43	. 70	2. 90**	6. 49**	10. 25**	4. 39**	6. 64**	5. 73**
Storage temperature	1	. 12	1. 15**	2. 84**	. 28	1. 22**	3. 40**	. 01	. 82**	1. 75**
SECOND CROP YEAR										
Mature:										
Variety	4	17. 98**	2. 87**	12. 33	2. 44**	2. 31*	1. 50	9. 25**	27. 52**	3. 06**
Storage time	3	. 72	3. 16**	2. 27	6. 23**	23. 26**	26. 81**	19. 63**	19. 60**	17. 69**
Storage temperature	1	1. 25*	. 16	13. 91	. 54*	. 18	. 50	. 65	. 03	. 49
Immature:										
Variety	3	40. 98**	3. 62**	41. 02**	3. 57**	2. 71**	. 94	1. 64	15. 13**	. 72
Storage time	3	. 72	2. 96**	6. 23**	3. 79**	13. 77**	20. 54**	23. 15**	23. 24**	9. 37
Storage temperature	1	. 01	. 12	6. 93	. 03	. 39	3. 12	. 59	. 63	1. 04

All apples, temperatures combined:										
Variety	3	126. 45**	11. 10**	106. 86**	9. 97**	6. 23**	2. 01	14. 27**	78. 25**	1. 90
Storage time	3	2. 12	9. 94**	15. 27**	18. 27**	66. 72**	88. 39**	79. 47**	83. 41**	48. 83**
Maturity	1	4. 62	. 04	7. 15	3. 26**	. 27	. 18	9. 50	. 32	. 10
BOTH YEARS										
Mature, temperatures combined:										
Variety	4	76. 44**	6. 28	41. 26**	5. 07	4. 72	1. 44	26. 66**	69. 67**	5. 36
Storage time	3	3. 32	10. 32*	9. 47*	14. 83	60. 91**	88. 59**	43. 07**	40. 16**	38. 76**
Crop year	1	. 63	7. 71	21. 96	4. 98	18. 71*	3. 47	53. 28**	28. 81	25. 06

[1] *=Significant at the 5-percent level, **=significant at the 1-percent level.

TABLE 16.—*Coefficients of correlation for certain palatability characteristics between raw apples and sauce, and between raw and baked apples*[1]

Palatability characteristic	Raw related to—			
	Sauce		Baked	
	First crop year	Second crop year	First crop year	Second crop year
Sweetness	+0. 92**	+0. 94**	+0. 88**	+0. 89**
Tartness	+. 91**	+. 96**	+. 87**	+. 96**
Natural flavor	+. 83**	+. 91**	+. 82**	+. 90**
Off-flavor, absence of	+. 84**	+. 86**	+. 86**	+. 92**
Color of flesh	+. 52**			
Texture of flesh	+. 23		+. 22	
Texture of skin			+. 65**	
General acceptability	+. 75	+. 81**	+. 78**	+. 89**

[1] Apples were mature and grown in 1948 and 1949, first and second crop years, respectively; ** = significant at the 1-percent level.

Flesh texture and wholeness of baked apples.—When baked, the varieties of apples included in this study were distinctly different from each other in the quality characteristic of flesh texture. When baked, some samples of Delicious and Winesap apples scored between 5.0 and 4.0, indicating a firm to slightly soft texture (fig. 11). Most of the baked apples of the Golden Delicious, Jonathan, and Rome Beauty varieties and some of the Delicious and Winesap scored

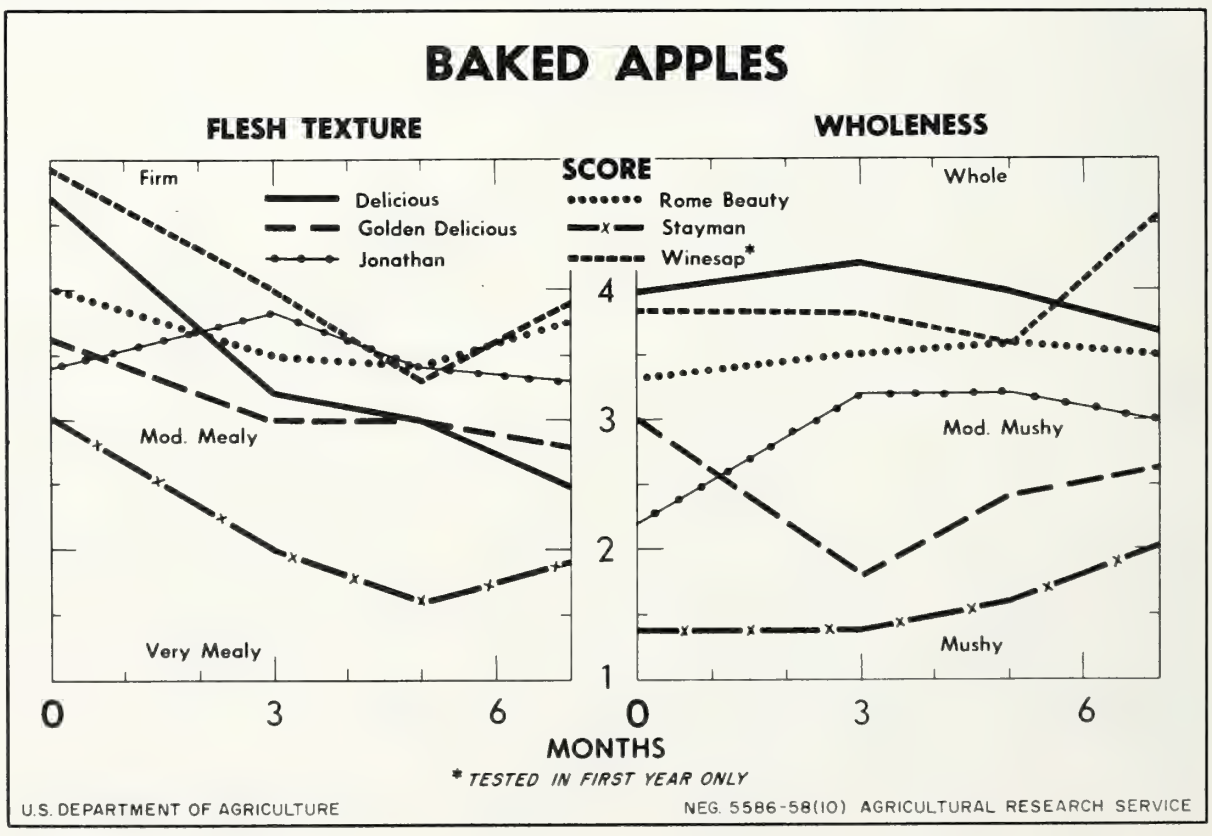


FIGURE 11.—Flesh texture and wholeness of baked apples before and after storage of mature apples at 40° F., mean scores for 2 crop years combined.

between 4.0 and 3.0 for flesh texture, described as slightly or moderately soft. Nearly all the baked Stayman apples scored between 3.0 and 2.0 in flesh texture, described as soft; some samples scored below 2.0.

Most of the apples baked after storage had softer flesh texture than those baked before storage. This finding is in agreement with that of Pfund (*33*), who associated short storage periods with the most desirable texture in baked apples. Correlation coefficients, computed in the first year only, indicated a nonsignificant relationship between scores for flesh texture of raw and baked apples.

The temperature at which the apples were stored had a significant influence on scores for flesh texture of baked apples in the first year only. Apples of nearly all varieties stored at 40° F. were softer when baked than those stored at 32°. Baked Jonathan apples were an exception; they were scored nearly the same for flesh texture whether the apples were stored at 32° or at 40°. Delicious apples baked after 7 months' storage at 32° were slightly soft, scoring 4.3; those stored at 40° were excessively soft when baked, scoring 2.5.

An overall comparison of wholeness in baked mature apples showed that those of the Delicious and Winesap varieties retained their shape well, scoring near 4.0 at most storage periods. The skins of Delicious apples clung to the flesh and showed very fine wrinkles over a large portion of the surface. Although Rome Beauties retained their shape quite well during baking (scored above 3.0), some separation between the skin and the flesh and some cracking and splitting of the skin were noted. Most samples of Golden Delicious and Jonathan apples after baking scored between 3.0 and 2.0 for wholeness. The skins of Golden Delicious showed some extensive cracking, slight shriveling, and complete separation from the flesh. Baked apples of the Jonathan variety exhibited some cracking of the skin and slight separation of the skin from the flesh. Baked Stayman apples scored lowest of all six varieties, usually between 2.0 and 1.0, described as badly cracked or mushy; these apples showed separation of skin from flesh as well as splitting of skin.

The four varieties of immature apples scored from 4.0 to 1.1 for wholeness when baked, with Delicious highest, Rome Beauty and Golden Delicious intermediate, and Stayman lowest.

According to the scores, wholeness of baked apples was not significantly influenced by the length of time the apples were stored. Apples baked after storage at 32° F. retained their shape better than those baked after storage at 40°, although differences in scores for wholeness were significant only for mature apples of the second year's crop.

Texture of applesauce.—Most of the varieties of mature apples made sauces which scored between 6.0 and 4.0 for texture, slightly smooth to slightly too granular (fig. 12). A slightly granular texture, a score of 5.0, was considered most desirable. Golden Delicious, Jonathan, and Stayman made sauces that usually were smoother than optimum, whereas sauces made from Delicious, Rome Beauty, and Winesap apples were more granular than optimum.

Of the unstored immature apples, the Rome Beauty variety made sauce nearest optimum in texture. Golden Delicious and Stayman sauces were slightly smooth, whereas sauce made from Delicious apples had moderately granular texture.

The length of time apples were stored did not significantly influence the texture of sauces made from them. The storage temperature of

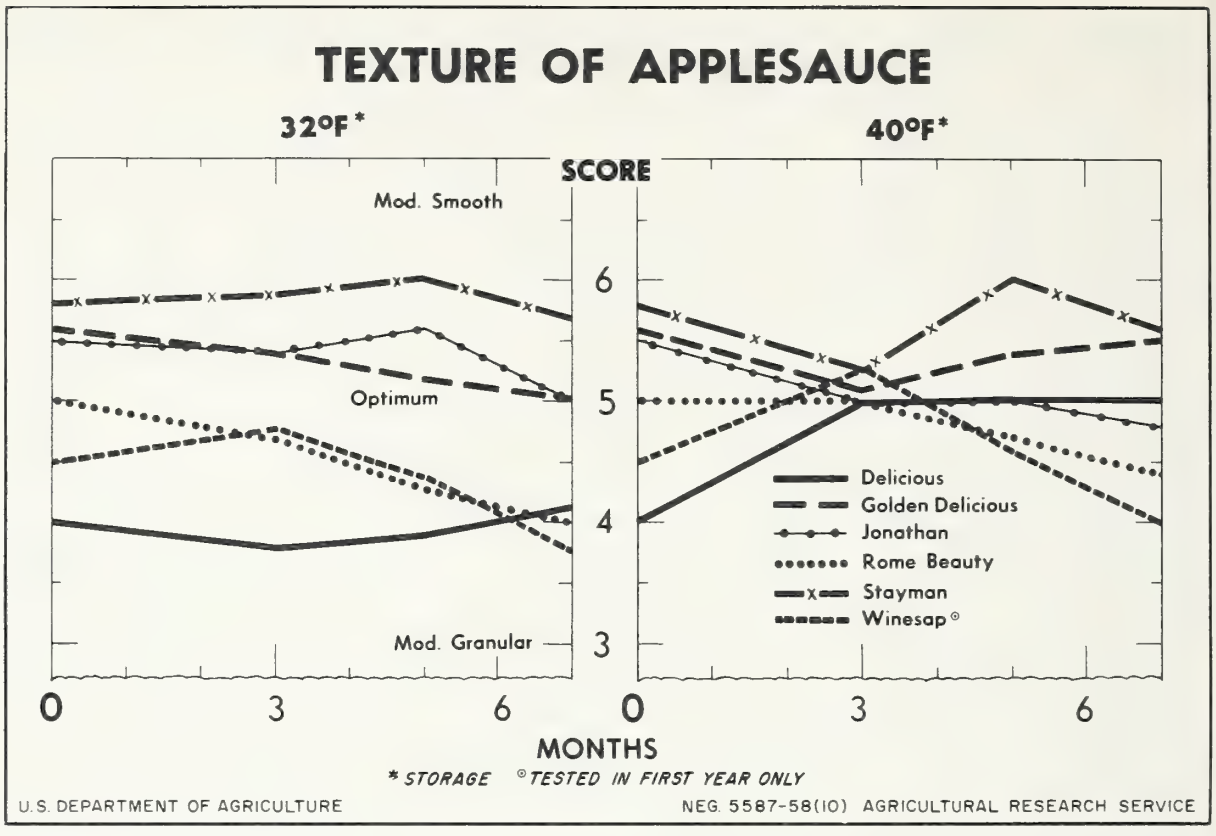


FIGURE 12.—Texture of applesauce before and after storage of mature apples at 32° and 40° F., mean scores for 2 crop years combined.

the apples had a significant effect on the texture of sauces made from the varieties used the first year, but not from those used the second year. At some storage periods, when the apples were stored at 32° F., Jonathan and Stayman sauces were smoother in texture but those made from the other varieties were more granular than when the apples were stored at 40°.

The coefficient of correlation between flesh texture of raw apples and texture of applesauce was not significant.

Consistency and linespread of applesauce.—For consistency of applesauce a score of 5.0 was considered optimum. Sauces given that score were thick enough to tend to hold their shape. Of the mature apples, Staymans stored for 3 months and all samples of the Jonathan variety made sauces that scored near optimum in consistency. Sauces thicker than optimum were made from samples of Rome Beauty and Winesap apples at all storage periods, from Staymans stored for 0 to 3 months, and from Golden Delicious stored for 3 to 7 months (fig. 13). Some samples of sauce made from Delicious apples were slightly thinner than optimum. Sauces made from unstored immature apples scored from 5.9 to 7.0 for consistency, or slightly to moderately thick, showing increasing thickness in the following order: Delicious, Golden Delicious, Rome Beauty, and Stayman.

Variation in the length of storage time of mature apples did not significantly influence scores for consistency of sauces. On the other hand, sauces made from immature apples before storage scored above 5.0, thicker than optimum, whereas those from apples stored for 3 months scored near 5.0.

When stored at 40° F. some varieties of apples the first year made sauces slightly thicker than those from the same varieties stored at 32°.

Linespread measurements for sauces made from mature apples before storage ranged from 3.1 to 7.2. Sauces from immature apples

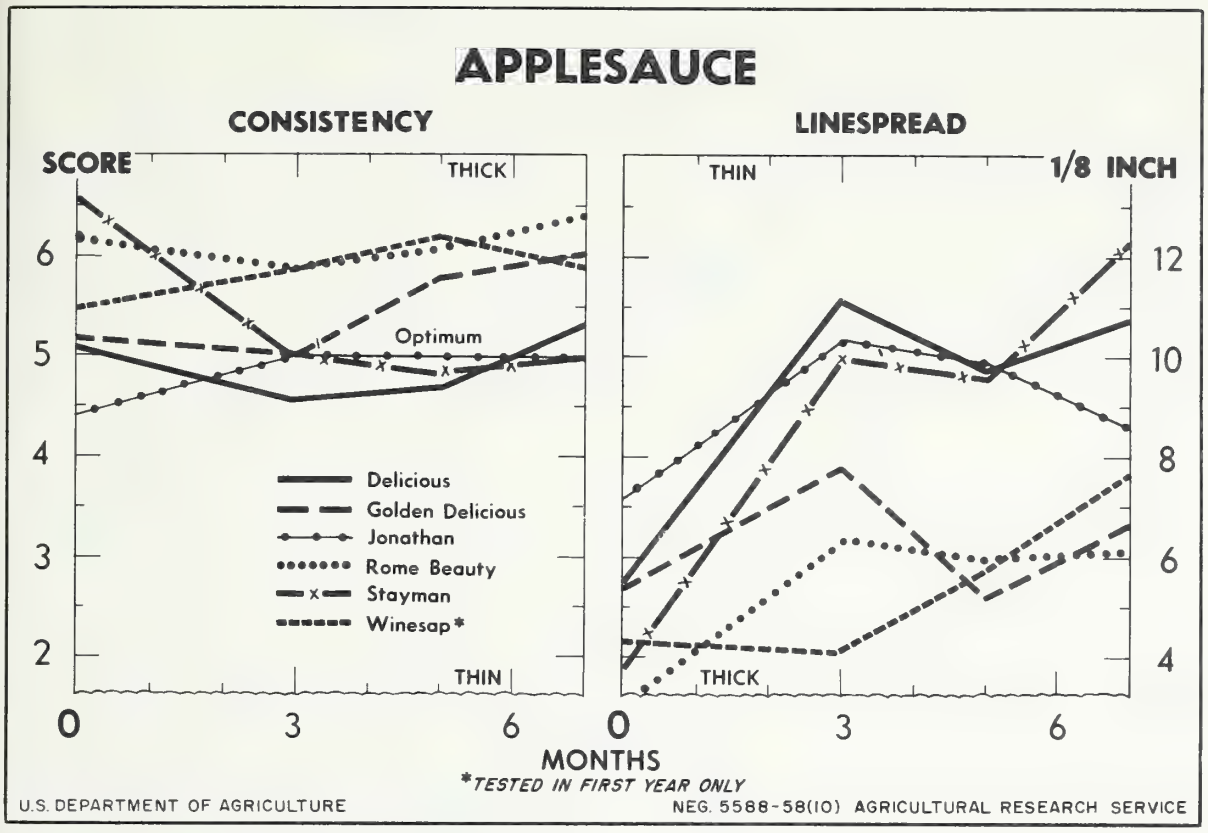


FIGURE 13.—Consistency and linespread of applesauce before and after storage of mature apples at 40° F., mean scores for 2 crop years combined.

ranged from 2.9 to 4.7. The linespread of sauces from all samples increased with storage of apples. In all probability this increase can be attributed to the increase in the thin part of the sauce. When apples were stored at 40° F., linespread of sauces made from some samples was greater than when apples were stored at 32°.

The apparent difference in significance of results from panel scores and linespread measurements may be accounted for by the fact that subjective judgment of consistency did not measure the thick and thin parts of the sauce as did the objective measurement of linespread. As panel members dipped into the sauces to evaluate consistency, blending of the sample occurred, whereas for linespread measurement the sauces were allowed to spread and separate.

Flavor Characteristics of Raw Apples, Applesauce, and Baked Apples

Mean scores for natural flavor, absence of off-flavor, sweetness, and tartness in raw apples of the different varieties studied, and in applesauce and baked apples prepared from them are shown in tables 17, 18, and 19. Tables 13, 14, and 15 reported analyses of variance of scores for raw apples, applesauce, and baked apples, respectively. Coefficients of correlation between raw and cooked apples were shown in table 16.

Natural flavor.—Combined scores for the two crop years show that in nearly all cases mature Stayman and Jonathan apples, both raw and cooked, were highest of the six varieties in natural flavor at every storage period (fig. 14), although scores related to variety were not always significantly different.

Mean scores for natural flavor in the mature apples before storage showed a range among varieties from 4.9 down to 4.1 on a rating scale,

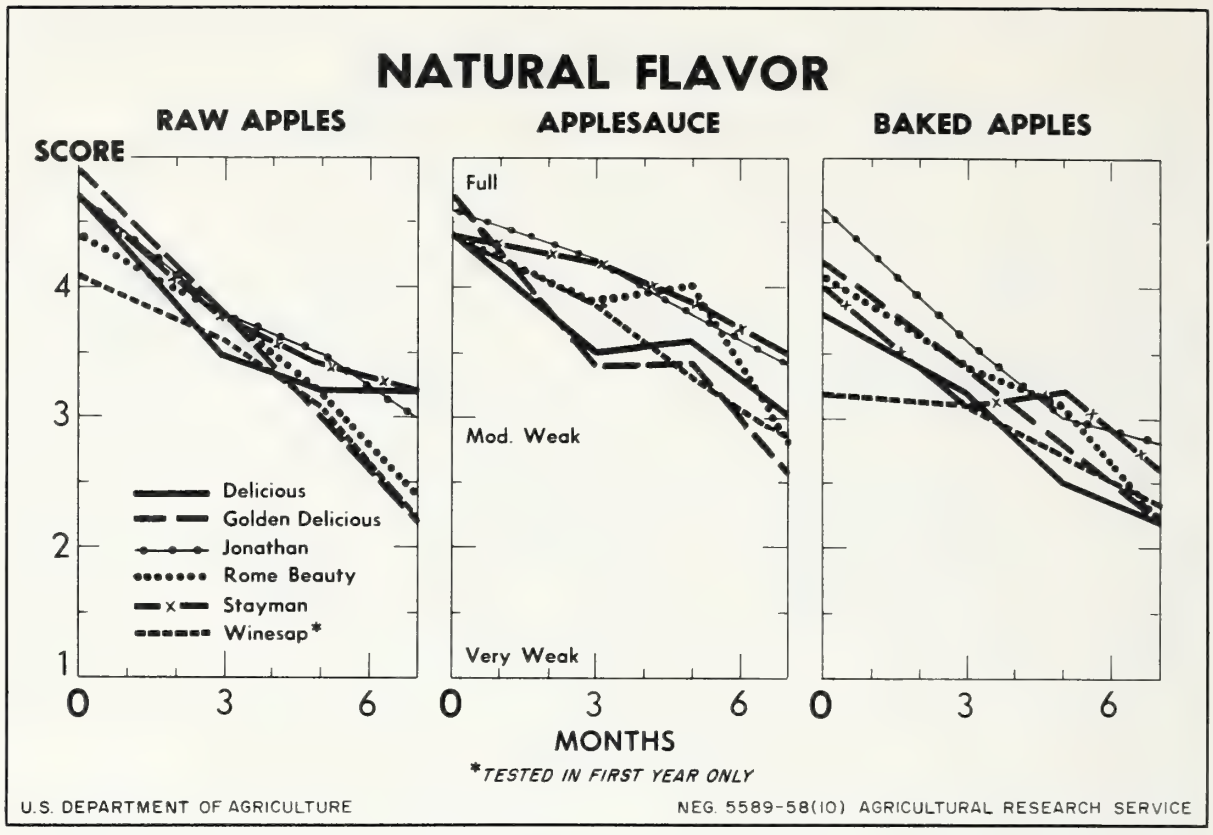


FIGURE 14.—Natural flavor of raw apples, applesauce, and baked apples before and after storage of mature apples at 40° F., mean scores for 2 crop years combined.

with 5.0 as optimum. Sauces made from these apples also scored above 4.0—from 4.7 to 4.4. When baked, all varieties except Winesap scored between 4.6 and 4.0. A lower score of 3.2 for baked Winesap can be attributed to the poor quality of the apples of that variety obtained for the study. Immature apples generally received lower scores than mature fruit of the same variety, whether judged raw, in sauce, or baked.

As expected, a decrease in natural flavor in all the apples was noted after storage. When judged raw, mature apples of all varieties scored above 3.0, indicating satisfactory flavor, for at least 5 months. After 7 months of storage, scores for Delicious, Jonathan, and Stayman apples were still above 3.0. Immature Stayman apples were satisfactory for 7 months, Delicious and Golden Delicious for 5 months, and Rome Beauty for 3 months.

When made into sauce, all the mature apples stored for as long as 5 months received satisfactory flavor scores of 3.0 or above. After 7 months of storage most varieties still made satisfactory sauce.

Of the baked apples, those of the Jonathan variety were acceptable in flavor after the apples had been stored for as long as 7 months at 32° F. but for only 5 months at 40°. Baked Rome Beauty and Stayman apples were satisfactory throughout 5 months regardless of storage temperature. Golden Delicious and Winesap apples had acceptable flavor scores when baked after 5 months' storage at 32° but maintained satisfactory flavor for only 3 months at the higher temperature. Delicious apples were satisfactory for baking when stored no longer than 3 months. Pfund (*33*) also found that flavor of cooked apples became less desirable as the length of apple storage increased.

Storage temperature significantly influenced scores for natural flavor of raw mature apples the first year, but neither mature nor immature apples the second year. Golden Delicious, Stayman, and

Winesap apples scored higher when stored at 32° F. than at 40°, whereas the other three varieties had natural flavor of about equal intensity at either storage temperature. Natural flavor of applesauce was not significantly affected by the temperature at which the apples were stored. When baked, apples stored at 32° usually had more natural flavor. Scores for natural flavor in baked apples were significantly different for storage temperature of apples in the first year only.

Coefficients of correlation show that natural flavor in raw apples was highly correlated with the same characteristic in sauces and baked apples. Correlation coefficients ranged from +0.82 to +0.91 in the two crop years.

Absence of off-flavor.—In a comparison of the different varieties of mature and immature apples before storage, the scores for absence of off-flavor ranged from 5.0 (none) down to 4.4 (very slight).

Made into sauce before storage, all varieties of mature apples scored from 5.0 to 4.5 for absence of off-flavor. When made from stored apples, however, Jonathan, Rome Beauty, and Stayman sauces had less off-flavor than those made from the other three varieties. Of the immature apples used for sauce, Stayman had the least off-flavor.

The variety of apples used for baking influenced scores for off-flavor in the first year only. Most varieties scored within the range of 4.8 to 4.4, showing very little or no off-flavor. Winesap scored lowest, 3.2, again showing the effect of low harvest quality.

With storage, all apples developed some off-flavor. If the quality of the apples was very good at harvest, off-flavor did not become so pronounced as to render the apples undesirable after 7 months of storage. Immature apples developed off-flavor at about the same rate as mature apples.

Applesauce, like the raw fruit, developed off-flavor with each increment in storage time of apples. There was some evidence, however, that when apples had no off-flavor at harvest (optimum score of 5.0), off-flavors showed up only to a slight extent in applesauce (score of 4.0 or above) for storage as long as 5 months. This was true for storage at 40° F. as well as at 32°.

As expected, all apples baked after storage had more off-flavor than those baked before storage. Some had strong off-flavors (scores below 3.0) when baked after only 5 months' storage. Nearly all the varieties baked after 7 months' storage had definite off-flavors and scored below 3.0.

Baking was a more critical test, since scores for baked apples were lower, even at harvest, than those for raw apples or applesauce, possibly owing to the baking method necessary for controlled experimental procedure. Increase of sugar and added seasonings commonly used in home practice would likely improve the flavor characteristics and the acceptability of baked apples.

In some instances, less off-flavor developed in mature and immature apples stored at 32° F. than in those stored at 40°. Likewise, sauces and baked apples prepared from apples stored at 32° had less off-flavor.

Scores for absence of off-flavor in raw apples were highly correlated with scores for that characteristic in sauces and baked apples. Correlation coefficients, on the basis of data for all varieties, storage temperatures, and times, ranged from +0.84 to +0.92 in the two crop years.

TABLE 17.—RAW APPLES: *Flavor characteristics before and after storage of apples, by crop year* [1]

Variety of apple and storage temperature	Storage time	Mean panel scores [2] for raw apples											
		Natural flavor			Absence of off-flavor			Sweetness			Tartness		
		Mature apples		Immature apples	Mature apples		Immature apples	Mature apples		Immature apples	Mature apples		Immature apples
		First crop year	Second crop year		First crop year	Second crop year		First crop year	Second crop year		First crop year	Second crop year	
Delicious:	*Months*												
32° F	0	4.9	4.5	4.1	5.0	5.0	4.7	4.8	4.4	4.7	5.5	5.9	5.7
	3	3.8	3.7	3.5	4.2	4.2	4.2	5.0	4.3	4.9	6.3	6.9	6.5
	5	3.8	3.0	2.8	4.1	3.3	3.4	4.2	3.7	4.1	6.5	7.1	6.7
	7	3.3	2.6	2.4	3.8	3.3	3.5	3.9	2.9	2.9	6.9	8.2	7.9
40° F	0	4.9	4.5	4.1	5.0	5.0	4.7	4.8	4.4	4.7	5.5	5.9	5.7
	3	3.9	3.1	3.4	4.7	3.7	4.3	4.0	2.9	3.7	6.7	7.9	7.4
	5	3.7	2.8	3.3	4.2	3.2	3.4	3.9	2.7	3.0	7.1	7.9	7.6
	7	3.4	2.9	2.7	3.6	2.7	3.1	3.4	2.2	2.1	7.3	8.6	8.3
Golden Delicious:													
32° F	0	4.9	4.9	4.1	5.0	4.9	5.0	5.0	4.1	5.3	5.0	5.5	4.5
	3	4.0	3.5	3.7	4.4	3.9	4.6	4.6	3.5	5.2	6.0	6.9	5.8
	5	3.9	2.9	3.1	4.5	3.4	3.6	4.1	3.2	4.3	6.3	7.9	6.5
	7	3.2	2.3	2.3	3.5	2.6	2.9	3.7	2.7	2.6	6.9	8.1	8.3
40° F	0	4.9	4.9	4.1	5.0	4.9	5.0	5.0	4.1	5.3	5.0	5.5	4.5
	3	4.2	3.5	4.0	4.6	3.7	4.2	4.3	3.3	3.8	6.2	6.9	6.5
	5	3.4	2.6	3.1	4.0	3.1	3.5	3.2	3.0	3.7	6.8	8.3	6.7
	7	2.8	1.5	2.5	3.1	2.1	2.9	2.9	2.5	2.5	7.5	8.7	8.5
Jonathan:													
32° F	0	4.9	4.5	-------	4.9	5.0	-------	5.7	5.1	-------	4.2	4.9	-------
	3	3.8	3.7	-------	3.6	4.0	-------	6.0	5.5	-------	4.2	4.8	-------
	5	3.9	3.5	-------	3.7	3.7	-------	5.6	4.9	-------	4.8	5.4	-------
	7	3.2	3.4	-------	3.4	3.5	-------	5.3	5.2	-------	5.1	4.8	-------

40° F	0	4.9	4.5	-------	4.9	5.0	-------	5.7	5.1	-------	4.2	4.9	-------
	3	3.8	3.8	-------	4.3	4.3	-------	5.8	5.5	-------	4.5	4.9	-------
	5	3.6	3.4	-------	3.6	3.5	-------	5.6	4.5	-------	4.8	6.0	-------
	7	3.0	2.9	-------	3.0	3.0	-------	4.6	4.7	-------	5.6	5.7	-------
Rome Beauty:													
32° F	0	4.0	4.8	3.8	4.8	5.0	4.8	5.2	4.7	5.7	5.3	5.6	5.0
	3	3.7	3.8	3.3	4.6	4.5	4.6	4.8	4.1	4.4	6.3	6.7	6.0
	5	3.5	3.0	2.6	4.6	3.5	3.9	4.7	3.7	4.2	6.8	7.2	8.0
	7	2.8	2.7	2.2	3.6	3.9	3.5	3.8	3.1	3.1	7.4	7.9	8.3
40° F	0	4.0	4.8	3.8	4.8	5.0	4.8	5.2	4.7	5.7	5.3	5.6	5.0
	3	3.8	3.8	3.4	4.6	4.4	4.2	4.3	3.7	4.5	6.8	6.9	6.3
	5	3.5	2.9	2.4	4.7	3.7	3.3	4.3	3.7	3.5	7.0	7.5	7.8
	7	2.6	2.1	1.9	3.3	3.4	2.9	3.6	3.1	3.2	7.4	8.3	8.7
Stayman:													
32° F	0	4.6	4.8	4.5	4.9	5.0	5.0	5.9	5.9	6.1	3.5	3.7	3.6
	3	4.3	4.2	4.2	4.2	4.3	4.4	5.9	5.7	5.6	4.4	4.1	4.1
	5	4.0	3.8	4.1	3.5	4.0	4.2	5.2	5.3	5.3	4.5	4.8	4.9
	7	3.1	3.6	3.4	2.7	3.4	3.3	4.1	4.7	5.2	5.9	5.5	5.1
40° F	0	4.6	4.8	4.5	4.9	5.0	5.0	5.9	5.9	6.1	3.5	3.7	3.6
	3	3.8	3.8	4.2	3.7	3.7	4.4	5.7	5.3	5.4	4.6	4.7	4.5
	5	3.7	3.0	3.3	3.8	3.0	3.1	5.1	4.0	4.3	4.7	6.2	5.7
	7	3.1	3.3	2.8	2.8	3.1	2.9	3.9	4.2	4.1	5.9	6.1	6.5
Winesap:													
32° F	0	4.1	-------	-------	4.4	-------	-------	5.3	-------	-------	5.3	-------	-------
	3	4.0	-------	-------	3.8	-------	-------	5.4	-------	-------	5.1	-------	-------
	5	3.7	-------	-------	3.6	-------	-------	5.5	-------	-------	4.9	-------	-------
	7	3.2	-------	-------	3.0	-------	-------	4.2	-------	-------	6.2	-------	-------
40° F	0	4.1	-------	-------	4.4	-------	-------	5.3	-------	-------	5.3	-------	-------
	3	3.6	-------	-------	3.9	-------	-------	5.1	-------	-------	5.2	-------	-------
	5	3.1	-------	-------	2.9	-------	-------	4.7	-------	-------	6.2	-------	-------
	7	2.2	-------	-------	2.3	-------	-------	3.6	-------	-------	6.9	-------	-------

[1] Mature apples were grown in 1948 (first crop year) and 1949 (second crop year); immature apples were grown in 1949.

[2] Mean of 15 scores (3 replicates by 5 judges). Natural flavor and absence of off-flavor scored from 5, highest to 1, lowest. Sweetness scored from 9, very undersweet to 1, very sweet and tartness scored from 9, very sub-acid to 1, very tart.

TABLE 18.—APPLESAUCE: *Flavor characteristics before and after storage of apples, by crop year* [1]

Variety of apple and storage temperature	Storage time	Mean panel scores [2] for applesauce											
		Natural flavor			Absence of off-flavor			Sweetness			Tartness		
		Mature apples		Immature apples	Mature apples		Immature apples	Mature apples		Immature apples	Mature apples		Immature apples
		First crop year	Second crop year		First crop year	Second crop year		First crop year	Second crop year		First crop year	Second crop year	
Delicious:	*Months*												
32° F	0	4.6	4.2	3.5	5.0	5.0	4.4	4.6	4.1	4.1	5.8	6.2	6.5
	3	3.8	3.2	2.9	4.2	3.9	3.4	4.0	3.7	4.1	6.7	7.3	7.0
	5	3.8	2.4	2.6	4.3	3.2	3.2	3.5	3.2	3.2	6.8	7.8	7.8
	7	3.0	2.1	1.9	3.5	2.7	2.4	3.6	2.4	2.3	7.2	8.6	8.4
40° F	0	4.6	4.2	3.5	5.0	5.0	4.4	4.6	4.1	4.1	5.8	6.2	6.5
	3	3.7	3.3	3.4	4.3	3.7	3.5	3.7	3.2	3.9	6.9	7.3	7.0
	5	4.1	3.1	2.9	4.5	3.3	3.3	3.6	3.3	3.4	6.3	7.3	7.5
	7	3.2	2.7	2.3	3.4	3.0	3.0	3.3	2.1	2.2	7.0	8.4	8.5
Golden Delicious:													
32° F	0	4.9	4.5	4.0	5.0	4.7	4.8	4.7	4.1	4.6	5.4	6.1	5.5
	3	4.3	3.3	4.1	4.8	3.2	4.1	4.3	3.8	4.2	6.1	6.7	6.3
	5	4.0	2.8	3.1	4.7	3.2	3.5	3.9	2.7	3.9	6.4	8.3	6.7
	7	3.4	2.5	2.8	3.5	2.5	3.3	3.2	2.4	2.3	7.0	8.4	8.4
40° F	0	4.9	4.5	4.0	5.0	4.7	4.8	4.7	4.1	4.6	5.4	6.1	5.5
	3	3.6	3.3	4.1	4.7	3.1	4.2	4.0	3.7	4.2	6.6	6.9	6.1
	5	4.2	2.5	3.0	4.7	2.7	2.9	4.1	2.7	3.9	6.5	8.2	6.8
	7	3.1	2.1	2.5	3.2	2.2	2.7	3.1	2.5	2.5	7.2	8.6	8.5
Jonathan:													
32° F	0	4.7	4.5	-------	4.9	4.5	-------	4.9	4.8	-------	4.9	5.1	-------
	3	4.3	4.4	-------	4.5	4.5	-------	5.1	4.9	-------	4.8	5.3	-------
	5	4.2	3.7	-------	4.2	3.9	-------	4.8	4.2	-------	5.4	5.9	-------
	7	3.3	3.9	-------	3.5	3.7	-------	4.8	4.5	-------	5.5	5.8	-------

40° F.	0	4.7	4.5	-------	4.9	4.5	-------	4.9	4.8	-------	4.9	5.1	-------
	3	4.2	4.3	-------	4.5	3.8	-------	4.8	5.0	-------	5.1	5.0	-------
	5	4.1	3.6	-------	3.8	3.7	-------	4.6	4.3	-------	5.0	5.9	-------
	7	3.4	3.4	-------	3.4	3.1	-------	4.6	4.4	-------	5.6	5.9	-------
Rome Beauty:													
32° F.	0	4.6	4.3	3.2	5.0	4.6	3.3	4.8	4.3	4.5	5.8	6.0	5.9
	3	3.9	3.9	3.9	4.3	4.4	4.3	4.4	4.1	4.2	6.1	6.4	6.2
	5	3.8	3.2	3.0	4.6	3.9	3.8	4.1	3.7	3.3	6.6	7.3	7.9
	7	2.9	2.7	2.2	3.4	3.4	3.1	3.2	3.1	2.7	7.3	8.1	8.3
40° F.	0	4.6	4.3	3.2	5.0	4.6	3.3	4.8	4.3	4.5	5.8	6.0	5.9
	3	4.1	3.7	3.6	4.7	4.0	4.1	4.3	3.7	3.9	6.1	6.7	6.9
	5	4.8	3.1	2.5	4.5	3.5	3.2	4.3	3.4	3.3	6.2	7.4	8.0
	7	3.2	2.3	1.4	3.1	3.2	2.4	3.5	3.0	2.7	6.9	8.3	8.8
Stayman:													
32° F.	0	4.1	4.7	4.0	4.9	4.4	4.7	5.0	5.1	4.9	5.5	5.1	5.1
	3	4.3	4.2	4.2	4.7	4.1	4.3	5.0	5.0	4.8	5.1	4.6	5.1
	5	4.2	3.5	4.3	4.8	3.9	4.1	4.9	4.2	4.5	4.7	5.3	5.2
	7	3.5	3.6	3.5	3.6	3.7	3.8	4.2	4.1	3.7	5.7	5.9	6.1
40° F.	0	4.1	4.7	4.0	4.9	4.4	4.7	5.0	5.1	4.9	5.5	5.1	5.1
	3	4.5	3.9	4.2	4.8	4.1	4.4	5.0	4.8	4.7	4.9	5.0	5.0
	5	4.6	3.2	3.5	4.8	3.7	3.4	4.8	3.8	4.1	5.0	5.5	5.7
	7	3.6	3.4	3.1	3.3	3.7	3.3	4.0	3.9	3.5	5.5	6.0	6.3
Winesap:													
32° F.	0	4.4	-------	-------	4.5	-------	-------	4.8	-------	-------	5.5	-------	-------
	3	3.8	-------	-------	4.0	-------	-------	4.7	-------	-------	5.2	-------	-------
	5	3.6	-------	-------	3.5	-------	-------	4.6	-------	-------	5.6	-------	-------
	7	3.2	-------	-------	3.1	-------	-------	4.2	-------	-------	6.2	-------	-------
40° F.	0	4.4	-------	-------	4.5	-------	-------	4.8	-------	-------	5.5	-------	-------
	3	3.9	-------	-------	4.3	-------	-------	4.5	-------	-------	5.5	-------	-------
	5	3.3	-------	-------	3.3	-------	-------	4.5	-------	-------	5.8	-------	-------
	7	2.8	-------	-------	2.4	-------	-------	3.1	-------	-------	6.8	-------	-------

[1] Mature apples were grown in 1948 (first crop year) and 1949 (second crop year); immature apples were grown in 1949.

[2] Mean of 15 scores (3 replicates by 5 judges). Natural flavor and absence of off-flavor scored from 5, highest to 1, lowest. Sweetness scored from 9, very undersweet to 1, very sweet and tartness scored from 9, very sub-acid to 1, very tart.

TABLE 19.—BAKED APPLES: *Flavor characteristics before and after storage of apples, by crop year*[1]

Variety of apple and storage temperature	Storage time	Mean panel scores[2] for baked apples											
		Natural flavor			Absence of off-flavor			Sweetness			Tartness		
		Mature apples		Immature apples	Mature apples		Immature apples	Mature apples		Immature apples	Mature apples		Immature apples
		First crop year	Second crop year		First crop year	Second crop year		First crop year	Second crop year		First crop year	Second crop year	
	Months												
Delicious:													
32° F.	0	3.7	4.0	3.5	4.4	4.7	4.4	3.6	4.1	4.3	6.6	6.3	6.3
	3	3.3	3.3	3.1	3.7	3.8	3.6	3.7	3.7	4.2	6.6	7.3	7.3
	5	3.0	2.1	2.2	3.2	2.8	2.7	3.2	3.0	3.0	7.0	7.3	7.8
	7	2.7	1.9	1.6	2.8	2.5	2.6	3.4	2.1	2.2	7.3	8.6	8.4
40° F.	0	3.7	4.0	3.5	4.4	4.7	4.4	3.6	4.1	4.3	6.6	6.3	6.3
	3	3.6	2.8	3.1	3.1	3.0	3.0	3.6	3.1	3.8	7.3	7.4	7.4
	5	3.0	2.0	2.0	2.9	1.9	2.1	3.6	2.4	2.7	7.0	7.9	7.8
	7	2.7	1.8	1.7	2.2	1.9	2.1	3.1	1.5	1.7	7.3	8.7	8.8
Golden Delicious:													
32° F.	0	4.1	4.3	4.3	4.5	4.5	5.0	4.5	3.5	4.4	6.0	6.4	5.8
	3	4.1	3.3	3.3	4.3	3.1	4.1	3.8	3.1	3.9	6.4	6.9	6.5
	5	3.6	2.5	3.0	3.7	2.7	3.1	3.6	2.5	3.5	6.5	8.1	6.9
	7	3.0	1.8	2.2	2.9	1.9	2.8	3.2	2.1	1.9	7.1	8.7	8.4
40° F.	0	4.1	4.3	4.3	4.5	4.5	5.0	4.5	3.5	4.4	6.0	6.4	5.8
	3	3.7	3.1	3.2	4.2	3.0	3.4	3.7	3.1	3.5	6.5	6.8	6.9
	5	3.4	2.2	2.9	3.6	2.6	2.7	3.6	2.4	3.6	7.0	8.3	6.8
	7	2.6	1.9	2.1	2.6	1.7	2.4	2.7	1.9	1.9	7.5	8.6	8.5
Jonathan:													
32° F.	0	4.6	4.5	-------	4.5	4.5	-------	4.5	4.6	-------	5.3	5.2	-------
	3	3.6	3.7	-------	3.5	3.9	-------	4.8	4.8	-------	5.3	5.2	-------
	5	3.8	2.8	-------	3.4	2.7	-------	4.7	3.7	-------	5.6	6.3	-------
	7	3.0	3.1	-------	2.9	3.1	-------	3.9	3.3	-------	6.0	5.8	-------

40° F.	0	4.6	4.5	-------	4.5	4.5	-------	4.5	4.6	-------	5.3	5.2	-------
	3	3.7	3.6	-------	3.5	3.8	-------	4.7	4.9	-------	5.3	4.9	-------
	5	3.2	2.9	-------	3.0	2.9	-------	4.5	3.5	-------	5.1	6.3	-------
	7	2.6	2.9	-------	2.3	3.1	-------	4.1	3.5	-------	6.3	6.1	-------
Rome Beauty:													
32° F.	0	4.3	3.9	3.3	4.5	4.3	3.9	4.5	3.8	4.2	5.6	6.3	5.9
	3	3.6	3.2	3.1	3.7	3.6	3.4	3.9	3.5	3.7	6.1	6.8	6.5
	5	3.6	2.5	2.7	3.8	3.0	3.2	3.8	3.0	3.7	6.4	7.9	7.7
	7	2.7	2.1	1.9	2.6	3.1	3.0	3.7	2.1	2.2	7.2	8.3	8.8
40° F.	0	4.3	3.9	3.3	4.5	4.3	3.9	4.5	3.8	4.2	5.6	6.3	5.9
	3	3.7	3.2	2.9	4.0	3.5	3.3	4.3	3.2	3.7	6.1	7.1	6.9
	5	3.7	2.5	2.4	3.8	3.2	3.0	3.8	2.4	3.5	6.3	7.7	7.9
	7	2.6	1.9	1.5	2.4	2.7	2.3	3.7	2.2	2.1	6.7	8.5	8.7
Stayman:													
32° F.	0	3.9	4.2	4.1	4.6	4.9	4.9	5.3	4.9	5.1	5.5	5.1	5.1
	3	3.6	3.6	3.5	3.8	4.0	3.8	4.6	4.7	4.3	5.0	4.7	5.3
	5	3.8	2.6	2.8	3.4	2.5	2.9	4.8	3.4	3.5	5.0	5.8	5.8
	7	2.6	2.6	2.8	2.3	2.7	2.8	3.5	2.9	2.9	5.8	6.1	6.2
40° F.	0	3.9	4.2	4.1	4.6	4.9	4.9	5.3	4.9	5.1	5.5	5.1	5.1
	3	2.7	3.5	3.6	2.3	3.8	3.6	4.5	4.7	4.2	5.9	4.3	5.1
	5	3.7	2.7	2.4	3.4	2.6	2.1	4.6	3.3	3.0	5.2	5.7	6.4
	7	2.6	2.5	2.5	2.2	2.8	2.3	3.7	2.7	2.8	5.9	6.2	6.9
Winesap:													
32° F.	0	3.2	-------	-------	3.2	-------	-------	4.8	-------	-------	6.2	-------	-------
	3	3.2	-------	-------	3.2	-------	-------	3.8	-------	-------	5.4	-------	-------
	5	3.3	-------	-------	2.9	-------	-------	4.3	-------	-------	6.0	-------	-------
	7	3.0	-------	-------	3.0	-------	-------	3.6	-------	-------	6.4	-------	-------
40° F.	0	3.2	-------	-------	3.2	-------	-------	4.8	-------	-------	6.2	-------	-------
	3	3.1	-------	-------	3.2	-------	-------	4.3	-------	-------	5.7	-------	-------
	5	2.7	-------	-------	2.4	-------	-------	4.1	-------	-------	6.2	-------	-------
	7	2.3	-------	-------	1.9	-------	-------	3.3	-------	-------	7.0	-------	-------

[1] Mature apples were grown in 1948 (first crop year) and 1949 (second crop year); immature apples were grown in 1949.

[2] Mean of 15 scores (3 replicates by 5 judges). Natural flavor and absence of off-flavor scored from 5, highest to 1, lowest. Sweetness scored from 9, very undersweet to 1, very sweet and tartness scored from 9, very sub-acid to 1, very tart.

Sweetness.—Panel scores for mature apples from both year's crops showed that the varieties differed considerably in sweetness. Compared with the standard of 5.0 for sweetness Jonathan, Stayman, and Winesap apples before storage were slightly lacking in sweetness (scores 5.3 to 5.9); Rome Beauty apples were near optimum in sweetness (score 5.0); and Delicious and Golden Delicious were slightly sweeter than optimum (score 4.6).

When cooked, Staymans were judged the most satisfactory of the unstored mature apples; they scored 5.0 in sauce and 5.1 as baked apples. The other five varieties were slightly too sweet both in sauce and when baked. Of the immature apples Stayman again was the variety that scored nearest optimum when cooked; the others made sauces and baked apples that were slightly too sweet. For practical purposes, the amount of added sugar could have been reduced to give cooked products nearer optimum in sweetness.

With storage, apples became sweeter. Those from the first year's crop increased in sweetness later than those the following year, and most of them had acceptable scores after 7 months of storage. At the 7-month period, immature apples were judged as sweet as mature apples.

As expected, applesauces became increasingly sweet as storage time of apples increased. However, only the sauces made from mature Golden Delicious and some samples of mature Delicious were excessively sweet after the apples had been stored for 7 months. Immature apples stored for 5 months made sauces that were not excessively sweet, but after 7 months' storage all varieties except Stayman made sauces that were too sweet to be satisfactory.

Apples baked after storage were also sweeter than those baked before storage. Of the mature apples, the Delicious and Golden Delicious varieties were excessively sweet when baked at the 7-month storage period; the others were slightly to moderately too sweet. Immature apples of all four varieties were too sweet for good quality baked apples after 7 months of storage.

Apples stored at 32° F. were less sweet than those stored at 40°. Storage temperature of apples did not have a significant influence on scores for sweetness of sauces or baked apples.

In both years' crops, sweetness of raw apples was significantly correlated with sweetness of sauces and baked apples. There was a slightly closer relationship between raw apples and sauce than between raw and baked apples, as indicated by slightly higher coefficients of correlation.

Tartness.—As shown by mean scores for tartness, on the basis of data for mature apples, two crop years combined (fig. 15), Jonathan and Stayman apples before storage scored near optimum when judged raw, in sauce, and after baking. Winesap was slightly to moderately lacking in tartness, yet more tart than Delicious, Golden Delicious, and Rome Beauty. These findings are in agreement with those of Pfund (*33*), who found that the Jonathan variety tended to retain high acidity as well as flavor in cooking.

The apples decreased in tartness with increases in length of storage time. Jonathan and Stayman varieties, slightly too tart before storage, were near optimum in tartness at the end of 7 months. Winesaps, only slightly lacking in tartness before storage, were satisfactory for 7 months. Delicious, Golden Delicious, and Rome

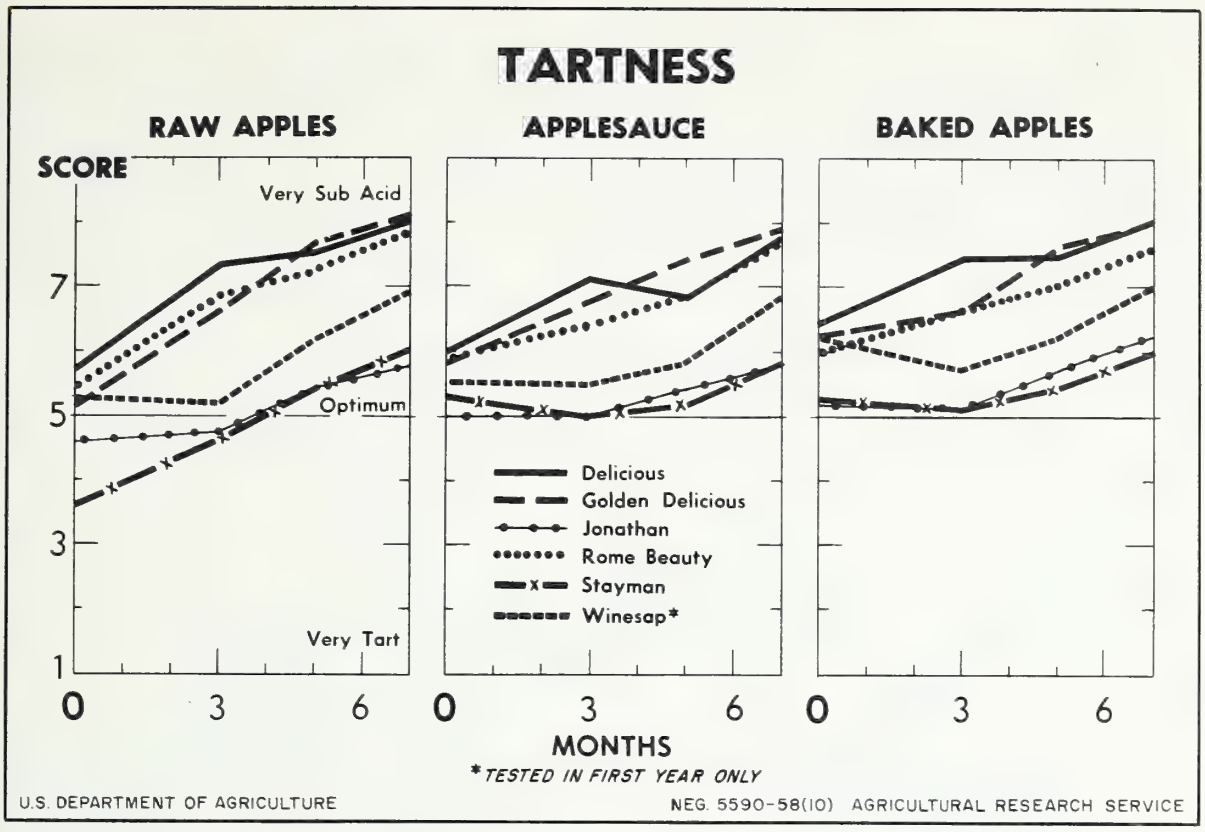


FIGURE 15.—Tartness of raw apples, applesauce, and baked apples before and after storage of mature apples at 40° F., mean scores for 2 crop years combined.

Beauty apples were moderately lacking in tartness after 5 months of storage and very lacking in tartness with longer storage.

The influence of storage time on tartness of sauces made from mature apples was much the same as on the raw fruit; the same varieties scored highest or lowest in each case. When stored immature fruit was used, Stayman sauces had acceptable scores for 7 months, Golden Delicious for 5 months, and Delicious and Rome Beauty for 3 months.

As was expected from the findings on raw apples and applesauce, all baked apples decreased in tartness with each increment in storage time of apples. Jonathan, Stayman, and Winesap apples had satisfactory scores for tartness when baked after as long as 7 months in storage, whereas Delicious, Golden Delicious, and Rome Beauty were very lacking in tartness earlier in storage.

Apples stored at 40° F. were less tart than those stored at 32°. Variations in storage temperature of apples had no apparent influence on scores for tartness of applesauce. Some varieties of apples were also less tart when baked after storage at 40°.

Tartness of raw apples was highly correlated with tartness in sauces and baked apples, with coefficients of +0.91 and +0.87, respectively, in the first year and +0.96 for both sauce and baked apples in the second year.

General acceptability of raw apples, applesauce, and baked apples

General acceptability refers to the appraisal of the product as a whole, taking into consideration all the characteristics. In this study, products scoring 3.0 (fair) or above were considered acceptable. Judged for general acceptability when raw, the Delicious, Golden

Delicious, Jonathan, Rome Beauty, and Stayman varieties scored 4.0 (good) or above before storage (figure 16 and table 20). All varieties rated fair to good in quality after 3 months' storage at 40° F. After 7 months' storage at 40°, Rome Beauty, Delicious, Jonathan, and Stayman scored about 2.6 for general acceptability, and Golden Delicious and Winesap scored 2.0 (poor). Apples rated higher in acceptability when stored at 32°.

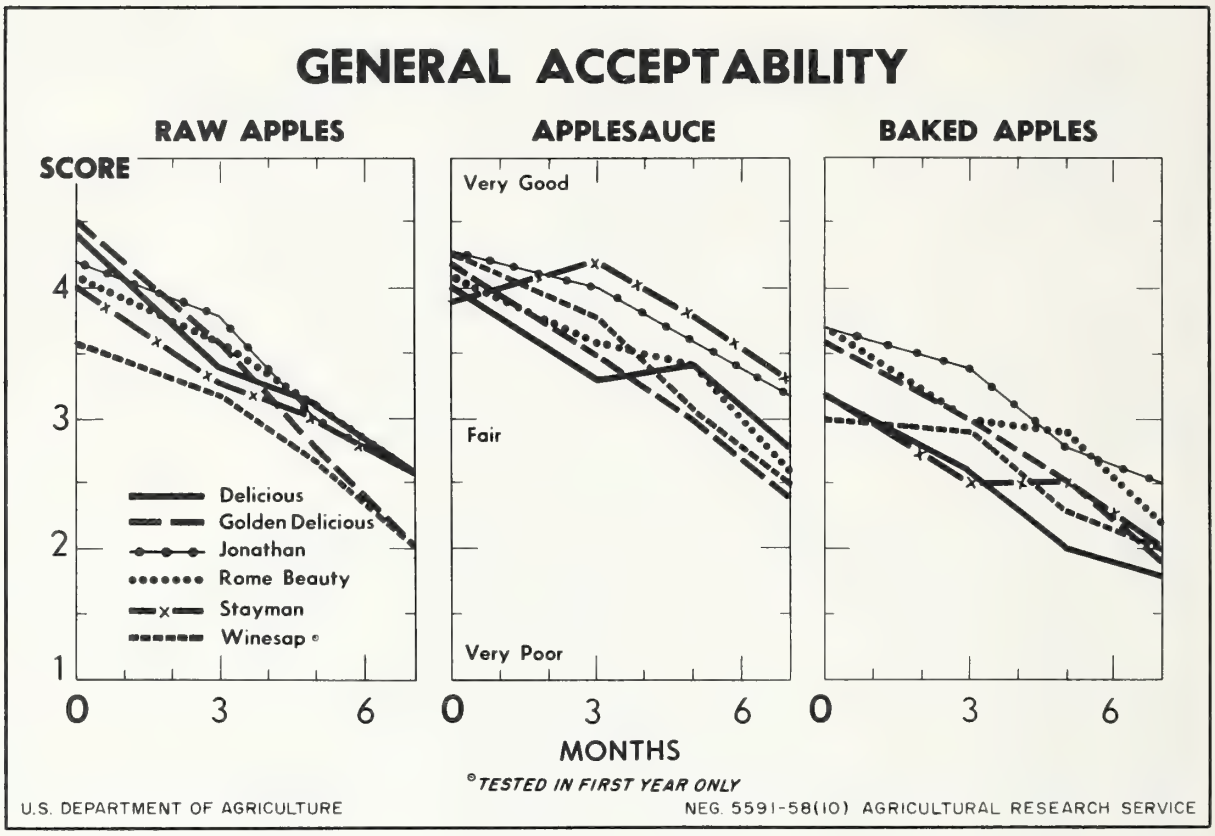


FIGURE 16.—General acceptability of raw apples, applesauce, and baked apples before and after storage of mature apples at 40° F., mean scores for 2 crop years combined.

Before storage, all six varieties of apples studied made sauces that were considered good. Stayman sauces improved after the apples had been stored for 3 months. With 7 months' storage of the apples, Jonathan and Stayman sauces scored slightly above 3.0; the other four scored approximately between 2.5 and 3.0. Five of the varieties were judged more acceptable in sauce than raw; Rome Beauty apples were equally acceptable in sauce and raw.

After baking, Jonathan apples were considered the most acceptable variety (good to fair at most storage periods). Baked apples of the Delicious variety were least acceptable at all storage periods of apples (fair to poor). This finding is in agreement with that of Magness (*23*), who stated that Delicious apples had poor cooking quality.

By means of correlation coefficients, scores for general acceptability of raw apples, applesauce, and baked apples were compared with scores for several palatability characteristics (table 21).

In raw apples, scores for natural flavor, absence of off-flavor, sweetness, and tartness showed highly significant correlations with general acceptability. The coefficients of correlation between natural flavor or off-flavor and general acceptability of raw mature apples, both years combined, were each +0.93; slightly lower coefficients were

found for immature apples. Although sweetness and tartness were also influencing factors in the scoring of general acceptability in raw apples, they were not of as great importance as natural flavor.

For applesauce, the coefficients of correlation showed that natural flavor, sweetness, tartness, and absence of off-flavor were more closely associated with general acceptability than were the other characteristics of texture, consistency, and color. Sweetness and tartness were more closely related to general acceptability in applesauce than in raw apples.

For baked apples, coefficients of correlation between general acceptability and various palatability factors differed in the two crop years and also according to the maturity of the apples. Scores for natural flavor, sweetness, and absence of off-flavor in all samples of baked apples (both years), flesh texture in baked mature apples in the first year, and tartness in baked mature and immature apples in the second year were significantly correlated with general acceptability. Natural flavor and off-flavor were more highly correlated with general acceptability than were sweetness, tartness, and flesh texture.

Apple quality in relation to histological structure

The quality of the apples used in this study was related to the histological structure of the apple skin. Least deterioration during storage was noted in Delicious apples, with increasing amounts in the other varieties in the following order: Rome Beauty, Jonathan, Stayman, and Golden Delicious.

Softening, shriveling, and weight loss during 7 months' storage corresponded closely to the amount of russet before storage and other irregularities of the cuticle (fig. 17). A striking illustration of the relation between russet and shriveling is found in the data for Delicious

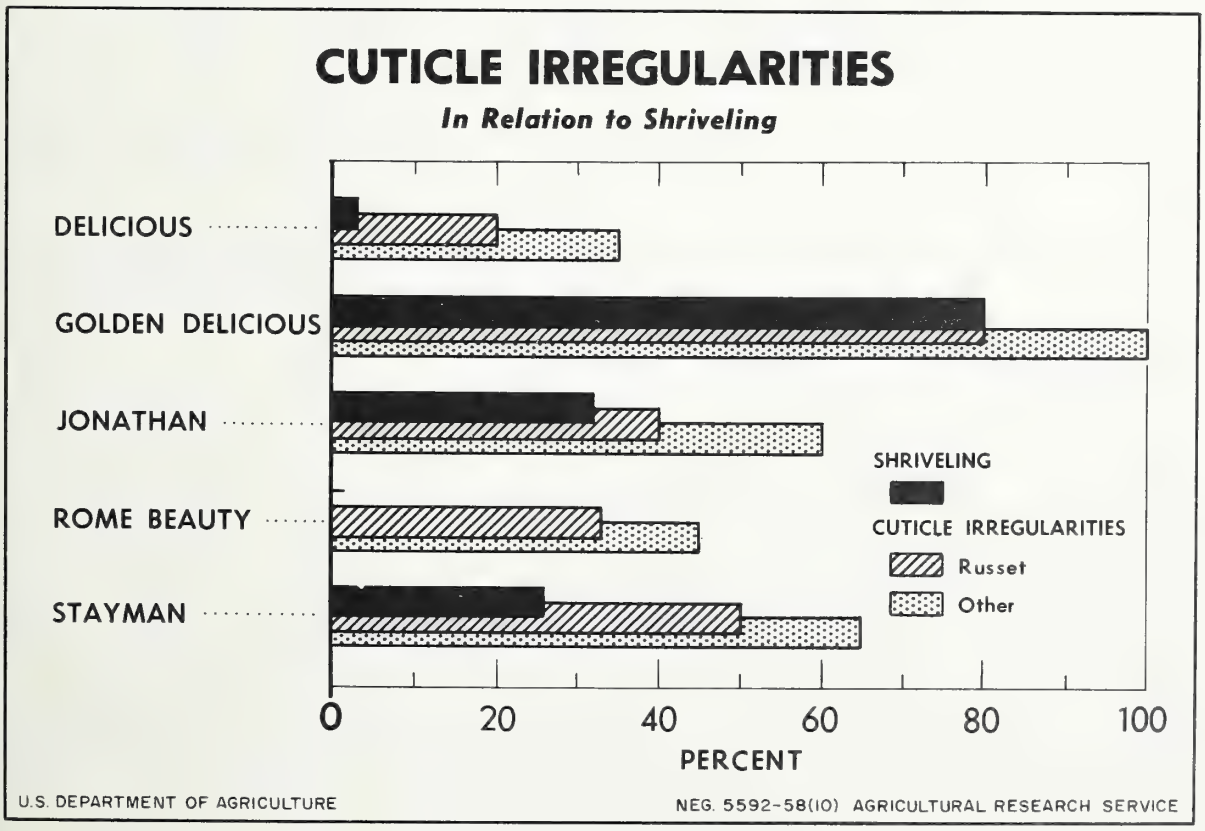


FIGURE 17.—Russet and other irregularities of apple cuticle in relation to shriveling of apples stored for 7 months at 32° F., 1 crop year.

TABLE 20.—GENERAL ACCEPTABILITY: *Mean scores for raw apples, applesauce, and baked apples before and after storage of apples, by crop year* [1]

Variety of apple and storage temperature	Storage time	Mean panel scores [2] for general acceptability								
		Raw apples			Applesauce			Baked apples		
		Mature apples		Immature apples	Mature apples		Immature apples	Mature apples		Immature apples
		First crop year	Second crop year		First crop year	Second crop year		First crop year	Second crop year	
Delicious:	*Months*									
32° F.	0	4.5	4.3	3.9	4.2	3.9	3.2	3.2	3.3	3.1
	3	3.9	3.9	3.6	3.2	2.7	2.6	3.1	2.7	2.8
	5	3.7	3.1	3.1	3.5	2.3	2.3	2.8	1.9	2.0
	7	3.4	2.6	2.9	3.0	1.9	1.6	2.6	1.7	1.7
40° F.	0	4.5	4.3	3.9	4.2	3.9	3.2	3.2	3.3	3.1
	3	3.8	3.1	3.2	3.4	3.2	3.3	2.9	2.3	2.7
	5	3.5	2.7	2.9	3.9	2.9	2.5	2.8	1.3	1.8
	7	3.3	2.0	2.3	3.2	2.4	2.1	2.3	1.3	1.4
Golden Delicious:										
32° F.	0	4.8	4.2	4.0	4.5	3.9	3.8	3.8	3.5	3.7
	3	4.0	3.2	3.8	4.3	3.3	3.7	3.8	2.6	3.0
	5	3.8	2.6	3.3	4.0	2.4	3.2	3.4	1.8	2.6
	7	3.1	2.0	2.2	3.4	2.1	2.4	2.9	1.5	1.9
40° F.	0	4.8	4.2	4.0	4.5	3.9	3.8	3.8	3.5	3.7
	3	4.0	3.3	3.5	3.9	3.1	3.7	3.5	2.4	2.6
	5	3.4	2.3	2.9	3.9	2.1	2.8	3.3	1.7	2.6
	7	2.5	1.4	2.3	3.1	1.7	2.3	2.3	1.5	1.8

Jonathan:										
32° F	0	4.2	4.3	----	4.3	4.3	----	3.5	3.9	----
	3	3.4	3.6	----	4.2	4.2	----	3.2	3.4	----
	5	3.4	3.2	----	3.8	3.7	----	3.2	2.4	----
	7	3.0	3.1	----	3.1	3.7	----	2.8	2.7	----
40° F	0	4.2	4.3	----	4.3	4.3	----	3.5	3.9	----
	3	3.7	3.8	----	4.0	3.9	----	3.5	3.2	----
	5	3.2	2.9	----	3.8	3.5	----	2.8	2.7	----
	7	2.6	2.6	----	3.3	3.1	----	2.3	2.7	----
Rome Beauty:										
32° F	0	3.6	4.6	3.5	4.1	4.1	3.1	3.7	3.7	3.2
	3	3.8	3.7	3.7	3.8	3.5	3.7	3.5	2.9	3.0
	5	3.4	3.2	2.7	3.4	3.2	2.9	3.6	2.3	2.4
	7	2.8	2.9	2.3	3.1	2.4	2.2	2.6	2.1	1.9
40° F	0	3.6	4.6	3.5	4.1	4.1	3.1	3.7	3.7	3.2
	3	3.6	3.5	3.4	3.9	3.4	3.5	3.4	2.7	2.5
	5	3.3	2.9	2.4	3.8	3.0	2.4	3.4	2.4	2.1
	7	2.8	2.5	2.0	3.0	2.2	1.5	2.5	1.8	1.5
Stayman:										
32° F	0	4.0	4.1	3.8	3.7	4.1	3.7	3.0	3.5	3.0
	3	4.0	3.8	3.8	4.3	4.3	4.2	2.9	3.0	2.7
	5	3.5	3.5	3.7	4.2	3.5	4.0	3.0	2.2	2.2
	7	2.9	3.0	2.9	3.5	3.4	3.3	2.2	2.0	2.5
40° F	0	4.0	4.1	3.8	3.7	4.1	3.7	3.0	3.5	3.0
	3	3.1	3.5	3.8	4.3	4.2	4.1	2.2	2.8	2.7
	5	3.6	2.5	2.8	4.2	3.3	3.3	2.9	2.1	1.7
	7	2.5	2.8	2.3	3.2	3.4	2.9	2.1	1.9	1.9
Winesap:										
32° F	0	3.6	----	----	4.3	----	----	3.0	----	----
	3	3.5	----	----	3.5	----	----	3.0	----	----
	5	3.1	----	----	3.5	----	----	2.8	----	----
	7	2.8	----	----	3.0	----	----	2.5	----	----
40° F	0	3.6	----	----	4.3	----	----	3.0	----	----
	3	3.2	----	----	3.8	----	----	2.9	----	----
	5	2.7	----	----	3.1	----	----	2.3	----	----
	7	2.0	----	----	2.5	----	----	2.0	----	----

[1] Mature apples were grown in 1948 (first crop year) and 1949 (second crop year); immature apples were grown in 1949.

[2] Mean of 15 scores (3 replicates by 5 judges). A score of 5 represents highest and 1, lowest.

TABLE 21.—*Coefficients of correlation relating general acceptability to palatability characteristics of raw apples, applesauce, and baked apples* [1]

Form of preparation, maturity of apples, and crop year	General acceptability related to—								
	Natural flavor	Sweetness	Tartness	Absence of off-flavor	Texture	Consistency	Color	Wholeness	Texture of flesh
RAW APPLES									
Mature, first crop year	+0. 92**	+0. 43**	−0. 36*	+0. 89**					
Mature, second crop year	+. 93**	+. 69**	−. 70**	+. 96**					
Immature	+. 90**	+. 79**	−. 82**	+. 92**					
Mature, both crop years	+. 93**	+. 56**	−. 54**	+. 93**					
APPLESAUCE									
Mature, first crop year	+. 86**	+. 61**	−. 57**	+. 81**	+0. 45**	−0. 20	+0. 60**		
Mature, second crop year	+. 97**	+. 92**	−. 90**	+. 88**	+. 25	−. 51**	+. 76**		
Immature	+. 98**	+. 90**	−. 91**	+. 89**	+. 78**	−. 32	+. 79**		
Mature, both crop years	+. 93**	+. 87**	−. 77**	+. 84**	+. 36**	−. 35**	+. 68**		
BAKED APPLES									
Mature, first crop year	+. 88**	+. 34*	−. 26	+. 90**				−0. 02	+0. 43**
Mature, second crop year	+. 96**	+. 86**	−. 73**	+. 94**				−. 20	+. 17
Immature	+. 94**	+. 88**	−. 73**	+. 89**				−. 22	+. 15
Mature, both crop years	+. 93**	+. 65**	−. 51**	+. 92**				−. 10	+. 29*

[1] Mature apples were grown in 1948 (first crop year) and in 1949 (second crop year); immature apples were grown in 1949; *= significant at the 5-percent level, **=significant at the 1-percent level.

and Golden Delicious apples. In Delicious apples 20 percent of the skin segments showed russet and in Golden Delicious, 80 percent; after 7 months' storage 3 percent of the Delicious and 80 percent of the Golden Delicious were shriveled. These findings confirm and extend those reported by Pieniazek (*34*).

Delicious and Rome Beauty, the varieties that showed the best keeping quality, had the smoothest, most homogeneous, and least interrupted cuticle; Delicious also contained the best developed cutin deposits between and below the epidermal cells. Although Golden Delicious contained almost as much supplementary cutin as Delicious apples, the broken, channeled, eroded, and porous cuticle contributed to this variety's poor storage quality. The cuticle of Stayman apples also was broken, channeled, eroded, and porous, but slightly thicker than that of the other varieties. The cuticle of Jonathan apples, although homogeneous, was channeled, and this variety had only very small deposits of supplementary cutin.

In general, apples showing deep-staining capacity and low incidence of birefringent crystalline bodies in hypodermal cell walls had good storage quality. The depth of the hypodermis or the thickness of the hypodermal cell walls apparently had no bearing on the keeping quality of the apples.

Deterioration of apples in storage showed some relation to the characteristics of cortex parenchyma cell walls. In Delicious and Rome Beauty tissues the cell walls showed more intense overall staining capacity and fewer instances of rupture and birefringent bodies than in the other varieties, which may be an indication of greater stability in composition.

Palatability scores for skin texture of apples from the second year's crop indicated that Golden Delicious had the most tender skin and Stayman the least tender. The tenderness of Golden Delicious skin can be attributed to the high incidence of surface and internal interruptions in the cuticle, combined with shallow hypodermis. The low scores for skin texture received by Stayman apples probably were influenced by the very firm flesh texture; the thick cuticle and hypodermis in the Stayman variety also could contribute to its skin toughness.

The only change in waterproofing layers due to steaming which was visible microscopically was a somewhat lessened staining capacity. This change, combined with softening of hypodermal cell walls, may account for the more tender skins in baked than in raw apples. After baking, Delicious apples had the toughest skin, although neither cuticle nor hypodermis was deeper than in the other varieties. Skin toughness of Delicious apples may be related to the relatively uninterrupted character of the cuticle, extensive supplementary cutin deposits, and the apparently more stable composition of hypodermal cell walls as evidenced by deep-staining capacity.

In the Delicious variety, separation of skin from flesh during baking was negligible—less than in any other variety. The hypodermis of the Delicious skin fell into a class apart from that of the other varieties, in that the cell walls were most deeply stained, before and after cooking, least swollen and spongy after cooking, and least subject to flaky breakdown. Jonathan hypodermal cell walls swelled the most, Stayman next, and Rome Beauty next; all showed considerable flaky breakdown. Hypodermal cell walls of Golden Delicious apples swelled little, but they showed other evidences of weakness after steaming.

Texture of sauces made from many varieties of apples may be influenced by the amount of vascular tissue in the cortex. However, gross observation of cleared slices led to the conclusion that differences among varieties in this study were not sufficient to explain variations in firmness of cooked tissues on that basis alone. Firmness of apple flesh after cooking may depend also on the amount and kind of cellulose, hemicellulose, and pectins originally present, and on the extent of hydrolysis or alteration of these substances during storage and during cooking, with consequent softening and rupture of cell walls and separation of cells.

The flesh of Delicious apples. most firm in texture of all varieties when cooked, had small cells and thin but intensely stained cell walls, least rupture whether raw or cooked, and least flaky breakdown when cooked. The Rome Beauty variety, next in firmness, also had small cells which when fixed raw were much like those of Delicious apples, but the cell walls were more affected by steaming than were those of the Delicious variety. Golden Delicious, Jonathan, and Stayman apples, which yielded softer or smoother cooked products, had slightly more lightly stained and more fragile cortical cell walls than the other varieties.

Greater concentration of pectins and hemicelluloses in cell walls of Delicious and Rome Beauty apples is indicated by greater staining capacity. The lower acidity of these varieties may indicate the presence of more cell wall solids in the other varieties (*42*). The degree of cooking breakdown may be influenced by differences in the water-soluble hemicelluloses (*52*) and pectins present. The amount of acid present is also said to influence hydrolysis of non-water-soluble hemicelluloses (*37*); on the other hand, Reeve and Leinback (*36*) found that high concentration of acid did not always mean great softening during cooking.

Palatability characteristics in relation to chemical constituents of apples

The palatability characteristics of raw and cooked apples in relation to several chemical constituents are shown in table 22. As might be expected, scores for tartness of raw apples, applesauce, and baked apples showed highly significant correlations with total acidity in apples. Correlation coefficients between natural flavor of raw and cooked apples and total acidity indicated that there was a tendency for raw apples high in acidity to score high in natural flavor, as well as the sauces and baked apples prepared from them. Natural flavor in sauces was influenced more by total acidity of apples than natural flavor in raw or baked apples. The pH of apples was highly correlated with tartness and with natural flavor and sweetness of raw apples, sauces, and baked apples. Natural flavor, sweetness, and tartness in sauces were more highly correlated with pH than were the same palatability factors in raw and baked apples.

As indicated by a highly significant correlation coefficient of -0.61, baked apples from varieties high in acidity showed a tendency to lose their shape. Trends in scores for flesh texture also indicated that raw apples high in acidity were crisp and not mealy. Consistency of sauce was not significantly correlated with total acidity.

Apples sweeter than optimum and lacking in natural flavor and tartness contained high percentages of reducing sugar. When these

TABLE 22.—*Coefficients of correlation relating several chemical constituents to selected palatability characteristics of raw apples, applesauce, and baked apples* [1]

Correlation factors	Raw apples	Applesauce	Baked apples
Total acidity related to—			
Natural flavor	+0. 46**	+0. 59**	+0. 43**
Tartness	−. 87**	−. 87**	−. 83**
Texture	+. 33**	----------	----------
Consistency	----------	−. 11	----------
Wholeness	----------	----------	−. 61**
pH related to—			
Natural flavor	−. 51**	−. 67**	−. 59**
Sweetness	−. 76**	−. 83**	−. 77**
Tartness	+. 79**	+. 83**	+. 83**
Reducing sugars related to—			
Natural flavor	−. 26*	−. 32**	−. 35**
Sweetness	−. 43**	−. 47**	−. 47**
Tartness	+. 46**	+. 46**	+. 51**
Total pectin related to—			
Texture	−. 08	−. 24*	+. 18
Consistency	----------	+. 03	----------
Pectic acid related to—			
Texture	−. 22	−. 00	−. 15
Consistency	----------	+. 06	----------
Wholeness	----------	----------	−. 00
Moisture content related to—			
Texture	−. 15	----------	----------
Consistency	----------	−. 33**	----------
Wholeness	----------	----------	−. 13

[1] Data for mature apples, two crop years combined; *=significant at the 5-percent level, **=significant at the 1-percent level.

apples were used in the preparation of sauces and baked apples, the greater sweetness and lesser degree of natural flavor and tartness were more pronounced than in the raw fruit.

In general, the correlation coefficients between total pectin, pectic acid, or moisture and various palatability characteristics were so small that they were of little consequence. There was an indication, however, that sauces made from apples high in total pectin scored low for texture because they were more granular.

Yields of prepared raw apple and applesauce

A comparison of preparation yields from each variety showed that Rome Beauty and Stayman apples gave the highest percentages of prepared raw apple and unsieved and sieved sauces (table 23). Losses due to rot and other discards had been deducted earlier.

As expected, the average raw weight per apple directly influenced the percentage yield of prepared raw apple. Small apples had a higher proportion of core and peel to cortex than large apples. Rome Beauty and Stayman varieties had the largest apples and gave the highest yields (range 70 to 75 percent). Delicious and Golden Delicious, intermediate in size, and Jonathan and Winesap, smallest of the varieties, gave intermediate and smallest yields (range 68 to 72

TABLE 23.—PERCENTAGE YIELDS AT EACH STORAGE PERIOD: *Prepared raw apple and unsieved and sieved sauces from apples, all storage temperatures, maturities, and crop years combined*

Variety of apple	Storage time	Apples used	Raw weight (average per apple)	Prepared raw apple [1]	Yield of sauce [2]		Unsieved pulp
					Unsieved	Sieved	
	Months	*Number*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*
Delicious	0	152	142	70. 1	74. 1	62. 6	11. 5
	3	156	145	70. 1	81. 8	77. 6	4. 2
	5	138	149	71. 6	82. 1	80. 2	1. 9
	7	161	139	69. 6	79. 0	77. 6	1. 4
Golden Delicious	0	120	174	71. 2	76. 4	74. 0	2. 4
	3	132	160	71. 3	82. 9	80. 9	2. 0
	5	139	153	70. 9	78. 6	76. 9	1. 7
	7	158	148	69. 2	76. 3	74. 9	1. 4
Jonathan	0	136	132	69. 4	75. 8	73. 7	2. 1
	3	162	124	71. 5	78. 1	76. 2	1. 9
	5	168	121	69. 5	78. 6	77. 0	1. 6
	7	169	119	68. 0	77. 0	75. 7	1. 3
Rome Beauty	0	116	200	75. 1	80. 3	75. 8	4. 5
	3	111	224	76. 4	85. 9	83. 8	2. 1
	5	132	211	74. 7	85. 6	84. 0	1. 6
	7	126	209	72. 6	81. 7	80. 4	1. 3
Stayman	0	84	252	75. 3	81. 8	79. 3	2. 5
	3	93	226	74. 4	85. 5	83. 7	1. 8
	5	104	210	71. 7	80. 7	79. 2	1. 5
	7	122	202	70. 3	79. 4	78. 0	1. 4
Winesap [3]	0	108	122	68. 3	79. 1	76. 4	2. 7
	3	90	130	72. 2	82. 1	79. 9	2. 2
	5	114	114	69. 4	77. 8	76. 2	1. 6
	7	129	110	64. 5	77. 0	75. 6	1. 4

[1] Pared and trimmed.
[2] Derived from a basis of 454 grams of prepared raw apple plus 158 grams of water and cooked for 15 minutes, then weighed.
[3] Tested in first year only.

percent) of prepared raw apple. Lopez (*22*) recently reported higher yields of prepared apple from larger apples of four varieties.

There seemed to be an inverse relation between the quality of the apples and the amount of unsieved pulp. Observations recorded in the laboratory on the condition of cooked apples in the preparation of sauce indicated that apples showing little or no breaking or mushing gave large percentages of unsieved pulp, whereas those moderately to very mushy yielded small amounts of unsieved pulp.

The yield of prepared raw apple related to storage time differed among the varieties: Jonathan and Winesap apples showed increases of 2 and 4 percent, respectively, during the first 3 months the apples were stored and decreases with each increment in storage time thereafter. Delicious apples, nearly constant in their yield after the first 3 months of storage, showed slight increases between the 3- and

5-month storage periods, with a decrease by 7 months. Yield of prepared raw apple in Golden Delicious and Rome Beauty apples showed little variation until after 3 months of storage, when there was a decrease. Stayman gave smaller yields with each increment in storage time.

Yields of unsieved sauces increased from 2.3 to 7.7 percent in all varieties of apples after the first 3 months of storage. The three varieties with the higher yields were Stayman, Rome Beauty, and Winesap. Before storage of apples, Stayman had a yield of 81.8 percent of unsieved sauce, whereas Rome Beauty and Winesap had 80.3 and 79.1 percent, respectively. After 3 months of storage, Stayman yielded 85.5 percent of unsieved sauce, Rome Beauty, 85.9 percent, and Winesap, 82.1 percent. After storage of 5 months, Rome Beauty apples gave the highest yield of all varieties, 85.6 percent, and Delicious was second highest with 82.1 percent. At the 7-month storage period, Rome Beauty, Stayman, and Delicious apples had the higher percentages of unsieved sauce.

During the first 3 months apples were stored, the yields of sieved sauce also increased in different varieties from 2.5 to 15.0 percent. Before storage, Stayman gave the highest percentage of sieved sauce, whereas after 3 months of storage it gave yields nearly identical with those of Rome Beauty. Delicious, Jonathan, and Rome Beauty showed slight or negligible gains between 3 and 5 months of storage. Of all varieties studied here, Rome Beauty gave the highest percentage yield of sieved sauce at the 5- and 7-month storage periods.

Difference in percentage yields of unsieved pulp from preparation of applesauce can account for the difference between yields of sieved and unsieved sauces. Statistical analysis of data the first year from applesauce cooked for 10, 15, or 20 minutes showed that the percentage of unsieved pulp was significantly higher from unstored than from stored apples. Data obtained the following year showed the same trends. The amount of unsieved pulp decreased with each increment in storage time. In a comparison of the six varieties before storage, Jonathan had the least unsieved pulp (2.1 percent), whereas Delicious had the most (11.5 percent). At the end of 7 months of storage the percentage of unsieved pulp was about the same for all varieties (1.3 and 1.4 percent).

Yields of prepared raw apple and unsieved and sieved sauces from most varieties tended to be higher from apples stored at 32° F. than from apples stored at 40° (table 24). In the preparation of sieved sauces, the percentage of unsieved pulp obtained from five varieties of apples showed a negligible effect of storage temperature. Exceptions were the sauces from Delicious apples in which there was less unsieved pulp from apples stored at 40° than from those stored at 32°—4.2 and 5.3 percent, respectively.

Yields of unsieved pulp and sieved and unsieved sauces were influenced more by total acidity than by any of the compositional factors studied. Delicious and Rome Beauty, lowest in acidity, had the highest percentage yields of unsieved pulp. Jonathan and Stayman apples, higher in acidity, gave lower amounts of unsieved pulp and higher yields of sieved and unsieved sauces. The data also indicated a tendency for the Delicious variety that was high in total pectin to yield high percentages of unsieved pulp.

TABLE 24.—PERCENTAGE YIELDS AT EACH STORAGE TEMPERATURE: *Prepared raw apple and unsieved and sieved sauces from apples, all storage periods, maturities, and crop years combined*

Variety of apple	Storage temperature	Apples used	Raw weight (average per apple)	Prepared raw apple [1]	Yield of sauce [2]		Unsieved pulp
					Unsieved	Sieved	
	°F.	Number	Grams	Percent	Percent	Percent	Percent
Delicious	32	303	143	70. 2	79. 4	74. 1	5. 3
	40	304	144	70. 4	79. 1	74. 9	4. 2
Golden Delicious	32	273	162	71. 2	79. 0	77. 2	1. 8
	40	276	156	70. 1	77. 9	76. 1	1. 8
Jonathan	32	312	125	69. 8	77. 1	75. 3	1. 8
	40	323	123	69. 4	77. 8	76. 1	1. 7
Rome Beauty	32	236	216	74. 8	83. 6	81. 2	2. 4
	40	249	206	74. 6	83. 1	80. 8	2. 3
Stayman	32	199	224	73. 3	82. 4	80. 6	1. 8
	40	204	221	72. 6	81. 2	79. 4	1. 8
Winesap [3]	32	213	122	68. 9	80. 4	78. 4	2. 0
	40	228	115	68. 3	77. 7	75. 7	2. 0

[1] Pared and trimmed.
[2] Derived from a basis of 454 grams of prepared raw apple plus 158 grams of water and cooked 15 minutes, then weighed.
[3] Tested in the first year only.

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